



**REAL OPTIONS AS A STRATEGIC MANAGEMENT FRAMEWORK: A CASE
STUDY OF THE OPERATIONALLY RESPONSIVE SPACE INITIATIVE**

THESIS

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AFIT/GRD/ENV/07-M2

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Abstract

The purpose of this research was to examine the potential for applying the concept of real options to the DoD acquisition system. The key premise of real options is the application of strategic decision making and flexibility in the face of future uncertainties. This thesis sought to answer three research questions, how could real options be applied to the acquisition system, how could the acquisition system benefit, and what are the potential challenges to implementation within the acquisition system. These research questions were addressed through a comprehensive literature and a case study of the Operationally Responsive Space (ORS) initiative. The ORS initiative is a transformational activity sponsored by the DoD to develop a strategy for deploying a flexible and responsive satellite system architecture for meeting the direct needs of the Combatant Commanders. Transcripts from interviews with six members of the ORS initiative, representing senior decision makers and project leads, were reviewed to gain insight into the goals and strategies of ORS. This research identified several consistent themes in the execution of the ORS initiative that present opportunities for the implementation of a real options framework in the defense acquisition system: the need for a new business strategy; the need for flexibility in our systems and processes to respond to future threats; and the need to exploit emerging capabilities and technologies. The culmination of this research is recommendations for further study of the real options, in particular how it might be codified for the use within the defense acquisition system.

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To my wonderful and understanding wife and son

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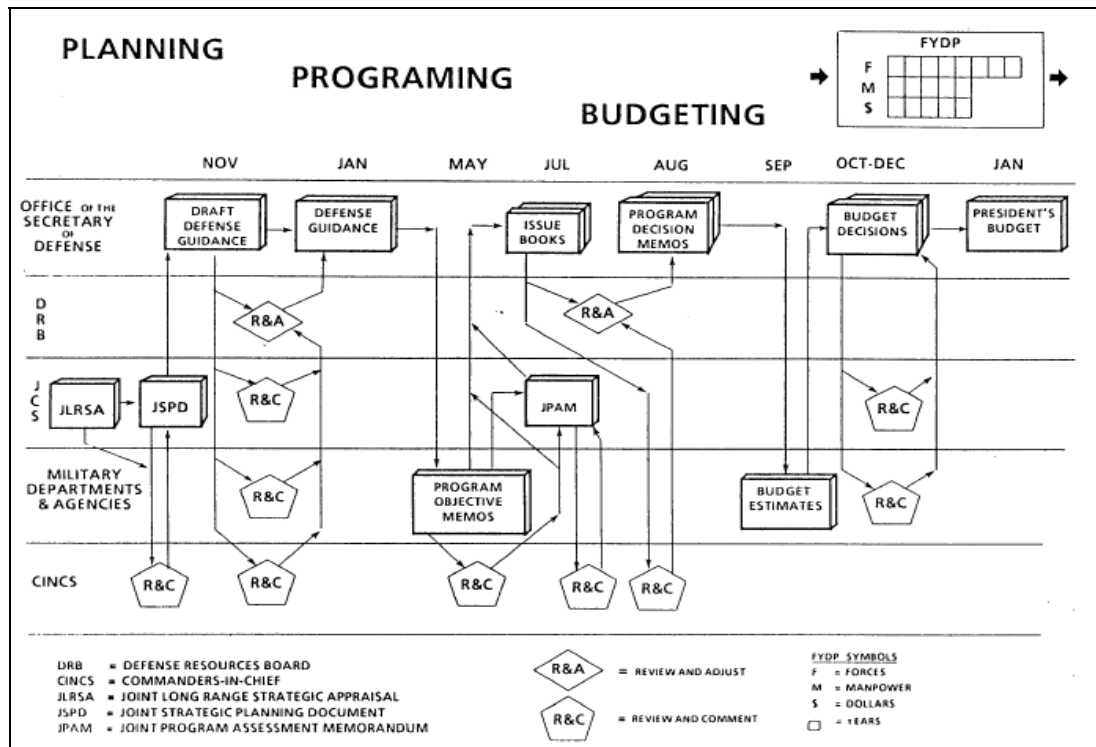
REAL OPTIONS AS A STRATEGIC MANAGEMENT FRAMEWORK: A CASE STUDY OF THE OPERATIONALLY RESPONSIVE SPACE INITIATIVE

I. Introduction

Research Motivation

On 21 January 1961, President John F. Kennedy appointed Robert S. McNamara as the 8th Secretary of Defense (Frank, 1999). Prior to his service as Secretary of Defense, McNamara served as the President for Ford Motor Company. As Secretary of Defense, McNamara sought to instill aspects from his corporate experience into the Department of Defense (DoD) (Frank, 1999). He pushed for a structured management control system for the DoD business processes, the results of which were the Programming, Planning, and Budgeting System (PPBS) and the Future Years Defense Budget (FYDP), as depicted in Figure 1 (Frank, 1999). The institution of PPBS and FYDP created a structured, analytical process for strategic decision making and investment decisions. More than 40 years later, the processes are still used in the management and execution of DoD resources (Glaros, 2003).

During McNamara's era, the DoD's principal concerns were the Soviet Union threat and the spread of communism. These threats were well defined and the DoD's goals were very clear: nuclear deterrence and retaliation, containing the Warsaw Pact, and being prepared for a Soviet Union advance through the Folda Gap. In the 21st century, such certainty is not guaranteed. The events of 11 September 2001 were a stark realization of this uncertainty and the bridge to a new age. Today, the DoD must deal with a rapidly changing and uncertain landscape.



To compete in this new landscape, the DoD must reevaluate its business processes. The PPBS and the FYDP were viable during the 20th century, but in the 21st century, the DoD must be able to keep pace with the speed of technological change and the uncertainty of the global landscape. One possible means of effecting this transformation is through the use of real options.

Real options is an analysis methodology for evaluating strategic investment decisions regarding physical assets or projects. The methodology can be defined as providing a right, but not an obligation, to take an action at sometime in the future for a predetermined price (de Neufville, 2005a). This definition addresses the strategic nature of the methodology, as it assigns greater value to projects with high degrees of flexibility in the face of future uncertainty. This concept builds upon the theory and application of

financial option valuation, applying the tenets of option valuation to the evaluation of physical assets and projects. In practice, real options relies on formulations derived from the Black-Scholes option pricing model (Rubash, 1996), a model described by Nobel Laureates Myron Black and Fischer Scholes (Rubash, 1996).

A number of industries have adopted real options methodologies to their practice. These industries are typically investment intensive, requiring large investments in markets with uncertain returns (Triantis & Borison, 2001) – characteristics that also describe the DoD. As a result of their operating environment and the need for managerial flexibility, to remain competitive, these industries are driven to place a high value on flexibility and stand to gain value from implementing real options, as described in Figure 2 (Copeland & Keenan, 1998a). Industries that have placed greater value on flexibility have recognized the merits of real options as a systematic framework for strategic management (Leslie & Michaels, 1997) and project valuation, as it recognizes the inherent benefit of integrating flexibility and off-ramps in the decision making process (Damodaran, 2005).

		Uncertainty Likelihood of receiving new information	
		Low	High
Room for managerial flexibility Ability to respond	High	Moderate flexibility value	High flexibility value
	Low	Low flexibility value	Moderate flexibility value

Figure 2. When Managerial Flexibility is Valuable (Copeland & Keenan, 1998a)

As the fundamental premise of real options is recognizing the value of strategic flexibility in highly uncertain markets, it seems well suited to the 21st century security environment. As the current and future security environment will be faced with uncertain and asymmetric threats, the merits of this methodology reflect the type of change the DoD is seeking in the transformation of its business processes.

Research Relevance

The events of 11 September 2001 were a catalyst for intense introspective assessment and the impetus for tremendous change within the DoD. Alberts and Hayes (2003) described this event as an “inflection point” in our history, marking the change to the 21st century security environment. They further acknowledged that this new century would face uncertainty and asymmetric threats to the security environment, intensified by the proliferation of weapons of mass destruction and a more interconnected world (Alberts & Hayes, 2003). These events awakened American citizenry to the uncertain future presented by the 21st century. It also emboldened our government leadership to take aggressive steps to change the DoD. Today, this change is referred as the Transformation of the DoD (OASD(PA), 2005).

Since the establishment of the DoD, there have been numerous efforts to refine and improve its business processes; in fact, the Defense Acquisition Performance Assessment (DAPA) report identified 128 studies to improve the acquisition system processes (DAPA, 2006). Each presidential administration has sought to provide the correct course for the DoD. President George W. Bush identified the Transformation of the DoD as a major initiative for his administration.

Our Nation is entering a period of consequences - a time of rapid change and momentous choices ... As President, I will give the Secretary a broad mandate - to challenge the status quo and envision a new architecture of American defense for decades to come. (OASD(PA), 2005)

Alberts and Hayes' (2003) notion of the extinction of the "symmetric Cold-War" era echoed this mandate and recognized that the American military's actions to organize, train, and equip were mired in a Cold-War paradigm. Recently conceived processes such as the Joint Capabilities Integration and Development System (JCIDS) continued this paradigm with a "slow and complex" process, which is considered ill suited for the dynamic landscape driven by rapidly emerging needs from combat operations (DAPA, 2006).

The future threats to the United States would most likely not come from a large conventional army, navy, or air force (OASD(PA), 2005). The United States and its allies had prevailed in the Cold War but lack the readiness to face the future challenges of an asymmetric threat, such as attacks on our shores or other unforeseen threats (OASD(PA), 2005). Under the Bush Administration, this process of defense transformation started in 2001 with the Quadrennial Defense Review (QDR) which identified the necessary changes for the U.S. defense strategy (OASD(PA), 2005).

The 2001 QDR reflected the DoD's views of the real changes needed in U.S. defense strategy (OASD(PA), 2005). A key observation was the need to achieve a balance between the development and acquisition of capabilities for the current war on terror and investments in capabilities to address emerging threats (OASD(PA), 2005). This hedge against potential threats and capabilities was a recognition that traditional mechanisms, such as the PPBS and the FYDP, were not well suited for the dynamic and

fluid nature of the current defense climate (Glaros, 2003). The DoD recognized the need for strategic flexibility and organizational adaptability in response to future uncertainties (Glaros, 2003).

The QDR presented the President and the Congress with a course for defense transformation. The transformation of the DoD would seek to achieve greater flexibility and adaptability in the services through an examination of the key issues for change: “changes in roles, missions, and organizations; needed changes in the law; pursuit of key enablers like space, information operations, surveillance systems, and special programs; changes to our strategic nuclear forces; new approaches for developing a 21st century civilian workforce; and improved business practices” (OASD(PA), 2005). These changes would enable the Army, Air Force, Navy, and Marine Corps to achieve the goals of the Defense Transformation initiative as presented in Table 1.

Table 1 <i>Defense Policy Goals</i> (OASD(PA), 2005)	
Defense Policy Goals	
1)	The ability to respond to unexpected dangers and emerging threats to ourselves or our allies
2)	The ability to dissuade potential adversaries from developing or deploying hostile capabilities
3)	The ability to deter hostile acts or counter coercion
4)	Should deterrence fail, the ability to defend the United States, our forces and friends, and defeat any adversary on our own terms

Research Objectives

The DoD has recognized that the highly uncertain security environment of the 21st century requires responsiveness and flexibility in its processes and operations. A real options framework presents the DoD with the opportunity to maximize its value and minimize its losses through a strategic application of flexibility. As Copeland and

Keenan (1998a) described, the DoD is an ideal environment for the application of real options because its operating environment is highly uncertain and it places value in a high degree of flexibility in its systems and processes. Based on these observations, this research will explore the potential for implementing a real options framework for the DoD acquisition system. The proposed framework considers the three approaches to implementing real options as examined by Triantis and Borison (2001): as a way of thinking, as an analytical tool, or as an organizational process. This framework will afford the DoD the opportunity to scale an implementation of real options according to its needs and desires.

Research Questions

The primary research question for this study is: “What are the opportunities for implementing a real options framework within the DoD Acquisition System?” The secondary research questions are as follows:

- How can the acquisition system apply a real options framework?
- How can the acquisition system benefit from a real options framework?
- What are the challenges to effectively implementing a real options framework?

Scope of Work

The focus of this research is a case study of the Operationally Responsive Space (ORS) Tactical Satellite (TacSat) experiments. ORS is a transformational initiative being undertaken by the DoD Office of Force Transformation (OFT). The ORS initiative

addresses the first goal of the Defense Policy Goal; the ability to respond to unexpected and emerging threats by providing a flexible and responsive space capability. The TacSat experiments are an integral construct in the ORS strategy, providing a means for proof-of-concept demonstrations and a test bed for new technologies.

This case study addresses the primary and secondary research questions by conducting a comprehensive review of the ORS initiative and the TacSat experiments, examining these efforts for elements of flexibility and optionality. This case study involved the examination of two sources of data: program artifacts and interview responses. Program artifacts were reviewed to gain insight into the principle and key strategies for the execution of the ORS initiative and the TacSat programs. The interview transcripts were reviewed to gain insight from program personnel on their perspectives on the execution of flexible processes in the ORS initiative efforts and their thoughts on the potential opportunities, benefits, and limitations for greater degrees of flexibility in the acquisition system.

Thesis Structure

Chapter II, Literature Review, will provide a review of the theory and practice of real options. The intent is to provide a perspective on the theory, utility, and potential applications of this methodology by communities of interest and communities of practice. A principal focus is the identification of strengths, limitations, and application by practicing industries with similar motivations to the DoD. Chapter III, Methodology, will describe the case study design and the rationale supporting the design choice. It will also present the methodology for conducting interviews and analyzing the data collected.

Chapter IV, Results, will present the results of this examination. The results will address the findings and insights gained from the review of program documentation and program personnel interviews. Chapter V, Conclusions and Recommendations, will present conclusions reached as a result of the case study and literature review. From these conclusions, recommendations for further action and future studies will be presented.

II. Literature Review

Introduction

This chapter will examine the literature reviewed for the study of real options and its benefits for the defense acquisition system. The chapter begins with a review of the evolution of real options, charting its development from theory to practice. Following the historical look, real options will be dissected to examine the key characteristics of the methodology. Once the elements of real options have been described, this methodology will be compared to more traditional tools, such as discounted cash flows and decision tree analysis. Having compared real options with other tools, the use of real options in industry will be evaluated: exploring methods of implementation and limitations. Lastly, this chapter will examine the nascent efforts of the federal government to exploit real options and the implications this has for the defense acquisition system.

Financial Options Pricing Theory

Option pricing theory is the established means for valuing financial options such as stocks and commodities (Copeland & Antikarov, 2001). At the heart of the option pricing concept is the notion of the option, a "contract between two parties in which one party has the right but not the obligation to do something, usually to buy or sell some underlying asset" (Rubash, 1996). In the financial community, this right is identified as either a "call" option (the right to buy something) or a "put" option (the right to sell something) (Copeland & Antikarov, 2001). Option pricing has been extensively studied

and as a result has been widely accepted (Copeland & Keenan, 1998a, 1998b; Luehrman, 1998a, 1998b; Sammer, 2002; Triantis & Borison, 2001).

The theory behind option pricing can trace part of its legacy to the works of Charles Caselli in 1877 with the publication of his book, “The Theory of Options in Stocks and Shares” (Rubash, 1996). The reference to Caselli’s work cites it as providing a public introduction to the concept of “hedging and speculation,” but lacking any “monumental theoretical base” (Rubash, 1996). The true mathematical foundation began with the mathematics dissertation of Louis Bachelier, “Theorie de la Speculation” (1900). Bachelier’s work served as the foundation of subsequent mathematical works of Paul Samuelson (1955), Richard Kruizenga (1956), and A. James Boness (1926).

Option theory took a large step forward in 1973 with the discussions and works of Fischer Black, Myron Scholes, and Robert Merton on “arbitrage-free” solutions and how to value them (Copeland & Keenan, 1998a). The term “arbitrage-free” means that securities with exactly the same risk and return problems should be identically priced (Copeland & Keenan, 1998a), a key concept for option pricing and understanding real options. Black and Scholes established their work building upon the foundation of Boness’ (1926) dissertation (Rubash, 1996). Black and Scholes published works resulted in the Black-Scholes Option Pricing Model, for which they were subsequently awarded the Nobel Prize in economics (1997) (Glaros, 2003).

The Black-Scholes model calculates a theoretical call value or call premium for the option being evaluated. The following depicts the formulation of the Black-Scholes model:

$$C = SN(d_1) - Ke^{(-rt)}N(d_2) \quad (1)$$

Where,

C = Call Value / Call Premium
S = Current Stock Price
t = Time Until Option Price Expires
K = Option Striking Price
r = Risk-Free Interest Rate
N = Cumulative Standard Normal Distribution
e = Exponential Term

$$d_1 = \frac{\ln(S / K) + (r + s^2 / 2)t}{s\sqrt{t}} \quad (2)$$

$$d_2 = d_1 - s\sqrt{t} \quad (3)$$

Where,

s = Standard Deviation of Stock Returns
ln = Natural Logarithm

The Black-Scholes model can be conceptually described as two components. The first operator $SN(d_1)$ “derives the expected benefit from acquiring a stock outright” (Rubash, 1996). The second operator $Ke^{(-rt)}N(d_2)$ “gives the present value of paying the exercise price on the expiration day” (Rubash, 1996).

Since its publication, the Black-Scholes Model has continued to evolve through the contributions of other financial scholars, such as Robert Merton (1973, 1976) and Jonathan Ingerson (1976). Each additional contribution has sought to expand the methodology to address concepts not previously considered such as the distribution of dividends from free cash flows.

Options Pricing To Real Options

The Black-Scholes Option Pricing Model provides the theoretical basis for real options (Copeland & Antikarov, 2001). Real options apply the methodologies of option

pricing, used in the evaluation of financial options, to physical assets and projects (Copeland & Antikarov, 2001). Like financial options, real options give the owner of an option the right to buy or sell an asset, at a certain price and within a specified time, without the obligation to do so (Alleman, 2002). Leppard (2001) describes real options as a series of techniques for assigning value to the strategic flexibility managers have in the valuation of physical assets or projects. In the context of physical assets and projects, real options allows for the recognition that uncertainty and the ability to respond to that uncertainty can increase a project's value, with greater uncertainty providing more opportunity to create value (Faulkner, 1996).

The term "real options" was coined in the late 1970s by Stewart C. Myers, a professor at the Massachusetts Institute of Technology (MIT) Sloan School of Management (Mehta, 2005). Myers (1976) described real options in his paper "Determinants of Corporate Borrowing," in which he examined the reasons why growth companies borrow very little. Myers observed that these companies had growth options, to which he asserted that growth companies had the ability or flexibility to observe whether investment opportunities were positive and could then decide whether to invest. The flexibility of this option provided additional value for the firm (Mehta, 2005). This value is further increased as the uncertainty of the underlying asset increased (Myers, 1976).

There are several notable differences between financial options and real options. Alleman (2002) characterized these difference by describing what is known and unknown about each type of option. For financial options, the stock price, expiration date, and strike price are well known and function in well-developed markets (Alleman, 2002). In

contrast, real options lack the same well-developed market which makes it difficult to determine the analog variables for stock price and strike price; furthermore, the notion of a defined expiration date for a project is unlikely (Alleman, 2002). de Neufville (2003b) and Alleman (2002) both noted that it is also difficult to determine the volatility for the underlying risk asset for real options.

Anatomy of A Real Option

The similarity between financial options and real options extends to the types of options as well. Like financial options, real options can be defined as either a “call” option or a “put” option. “Call” options represent the right to buy the underlying asset at a prescribed exercise price; they are evaluated on the relationship between the option price and the exercise price. If the value of a “call” option exceeds the value of the exercise price, the option is said to be “in-the-money” (Copeland & Antikarov, 2001). If the value of the exercise price exceeds the value of the “call” option, the option is considered to be “out-of-the-money” (Copeland & Antikarov, 2001). In contrast to a “call” option, a “put” option represents the right to sell the underlying asset at a prescribed exercise price.

Real options are also defined by the style of the option. The various styles of options include American, European, Asian, and Bermuda. The discussions in this review will focus on both American options and European options. American options can be exercised at any point during its life before it expires (Copeland & Antikarov, 2001). Therefore, American options generally have a greater value as the option can be exercised at any point, thereby allowing the option to be exercised at a point when the

market volatility increases the option value the most. In contrast, European options can only be exercised upon maturity of the option (Copeland & Antikarov, 2001) which may cause it to possibly miss out on the potential for greater gains before option maturity. Contrarian positions exist which suggests that a “rational” trader would not necessarily exercise an American option early in an attempt to delay and gain more value on the option (Sapienza, 2003).

The value of a real option is defined by six characteristics. Copeland and Antikarov (2001) and Alleman (2002) agree on four of these basic characteristics. Copeland and Antikarov (2001) add two additional characteristics, a project’s risk-free interest rate and any potential dividends, to the list of characteristics. Each of the six characteristics is described in Table 2.

The final element in the anatomy of a real option is the type of strategic action taken on the underlying asset. These classifications of actions depict the type of flexibility exercised in strategic decision making (Alleman, 2002; Copeland & Antikarov, 2001). Alleman (2002) identifies several actions that might be exercised as presented in Table 3. These actions reflect the strength of real options, which is the ability to respond to the uncertainty of a project and its market conditions (Alleman, 2002). Leslie and Michaels (1997) and McGrath (1999) noted that this type of flexibility can affect an organization’s perception of uncertainty and entrepreneurship, thus changing management’s philosophy from one of “fear uncertainty and minimize investment” to “seek gains from uncertainty and maximize learning.”

Table 2 *Characteristics of a Real Option*

Characteristics	Effect on Value
1) The value of the underlying asset: the value of the physical asset, “whether it is a project, investment or acquisition”.	Increases
2) The exercise price: the money that will be spent if a call option is exercised or the money to be gained if a put option is exercised.	Decreases
3) The time to expiration of the option: The duration of time that the option is available to be exercised, with longer durations creating greater value.	Increases
4) The volatility of the market for the underlying asset: The risk of the underlying asset in the market, with higher degrees of market uncertainty generating greater value because of the potential for greater upside benefits.	Increases
5) The risk-free rate of interest for the life of the option: As the risk-free rate increases so to does the value of the options.	Increases
6) The dividends that may be paid out from the underlying asset: If dividends are paid the value of the option will be impacted.	Decreases

In addition to these simple actions, there are more complex interactions of options; these are referred to as compound options, rainbow options and compound rainbow options. Compound options are described as options on options (Copeland & Antikarov, 2001). In a compound option, the options available to a manager are contingent upon the options from previous phases of the project. Research & development (R&D) efforts are representative of the type of effort that might contain compound options. R&D efforts typically involve multiple phases such as design phase, engineering phase, test phase, and a production phase. Each phase contains the option to abandon, defer, switch, or contract at the end of the phase, before committing to any follow-on activities. Rainbow options are described as options driven by multiple sources of uncertainty (Copeland & Antikarov, 2001). Finally, there are compound rainbow options. A compound rainbow option is an option driven by multiple sources of uncertainty containing options on options (Copeland & Antikarov, 2001).

Table 3 *Types of Real Options and Descriptions*

	Type of Option	Reference
Defer	an American call option to delay the start of a project, giving management the opportunity to await the return of a favorable or “good” state of nature	(Alleman, 2002) (Copeland & Antikarov, 2001)
Abandon	an American put option which can be exercised at a predetermined fixed price, to salvage some value from an poorly performing project	(Alleman, 2002) (Copeland & Antikarov, 2001)
Contract	option to sell part of a project for a fixed price and downsizing the remaining operations, if the market conditions are in a down state	(Alleman, 2002) (Copeland & Antikarov, 2001)
Expand	Option to pay more to scale up the project, allowing operations to take advantage of markets in an up state	(Alleman, 2002) (Copeland & Antikarov, 2001)
Switch	Option to exercise a portfolio of call and put options, which enable switching between different modes of operation for a fixed cost.	(Alleman, 2002)
Shutdown and Restart	Option to shutdown and restart is the ability to cease or resume operations of at fixed cost predicated upon the state of the prevailing markets.	(Alleman, 2002)
Growth	Option to take advantage of future interrelated opportunities	(Alleman, 2002)

Real Options or Discounted Cash Flow

Discounted cash flow (DCF) and net present value (NPV) are traditional tools used for evaluation of projects and investment decisions. This method determines project value by discounting expected future cash flows at an appropriate risk-adjusted rate and then subtracts the cost of any investments (Copeland & Keenan, 1998a). The resulting value of this calculation is the project’s NPV. Projects are then evaluated on the

determined NPV. Projects with a positive NPV are accepted and projects with a negative NPV are rejected (Copeland & Keenan, 1998a).

The NPV is a function of free cash flows, the duration of the project, and the Weighted Average Cost of Capital (WACC). WACC is defined as the after-tax marginal cost of capital (Copeland & Antikarov, 2001). The formula for determining NPV is presented below.

$$NPV = -I + \sum_{t=1}^N \frac{E(FCF)}{(1+WACC)^t} \quad (4)$$

Where,

NPV = Net Present Value

I = Initial Investment

t = Life Expectancy of Project (Start =1, to Finish=N)

E(FCF) = Expected Free-Cash Flow

WACC= Weighted Average Cost of Capital

A limitation of the NPV formulation is that it does not assign a value to the capability of management to make certain strategic decisions (abandon, defer, shutdown, etc.) during the course of a project's life cycle. Harvey (1999) noted that these strategic options, are truly real options and do not generate value in standard DCF. These strategic decisions have a value which may alter the decisions made regarding a project's viability.

A simple example illustrates the difference that strategic flexibility has in project valuation (Harvey, 1999). The example contrasts a DCF evaluation, described in Figures 3, with a real options evaluation, described in Figure 5. The project timelines and project cash flows for this example are depicted in Figure 4.

In Figures 3 and 4, following the initial investment there is a 30% probability that the project will experience bad market conditions, at which management could change

the projects course. Following the second investment two additional decision points are created. In the upstate, the decision point leads to either an 80% probability of success or a 20% probability of failure. In the downstate, the decision point leads to either a 20% probability of success or an 80% probability of failure. The DCF method evaluates the project decision tree with the assumption that all events depicted will occur. The real options evaluation depicts management's flexibility to respond to market uncertainty.

Suppose a clothing company is considering introducing a new line of fashion. The project has a two year life. An initial investment of \$50 (cash flows are in thousands) is required to fund a year-long development phase. At the end of a year, a further \$50 is required for production and cash inflows from sales (net of selling expenses) will occur at the end of the second year.

There is some uncertainty about the amount of the cash inflows since it is unclear whether the market will embrace the new line. The firm currently believes that there is a 70% chance that the new line will be a winner. They also believe that the direction of fashions will become more apparent over the next year. In particular, there is an 80% chance that the direction over the next year will continue over the subsequent year.

This uncertainty, and the associated cash flows, are presented in Figure 4. Suppose also that the required return on projects of this type is 10%.

Standard capital budgeting techniques involve computing the expected net present value (NPV) as:

$$E[NPV] = -50 + \frac{-50}{1.1} + \frac{0.7(0.8(200) + 0.2(120)) + 0.3(0.2(90) - 0.8(100))}{1.1^2}$$

$$E[NPV] = -4.38$$

In which case the project would be rejected.

Figure 3. Abandonment Example, NPV (Harvey, 1999)

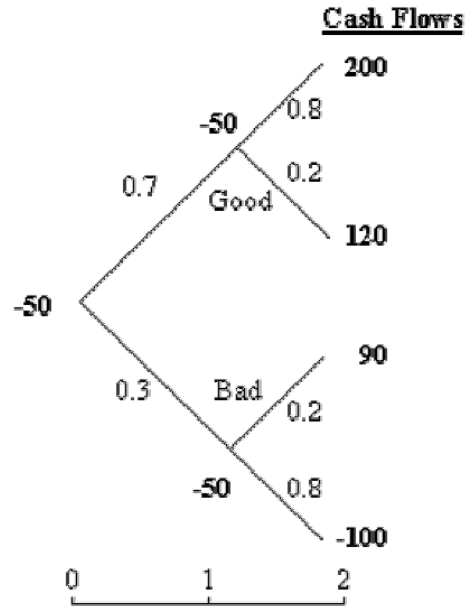


Figure 4. Abandonment Example, Decision Tree (Harvey, 1999)

Consider, however, the case where the firm has the option to abandon the project after the first year. In this case, the second phase of the project would only proceed if the market direction was favorable over the first year. If the market direction was unfavorable, the firm would abandon the project, since proceeding would cost a further \$50 and the expected present value (at time 1) of the case inflow is

$$(0.2(90) - 0.8(100)) / 1.1 = -\$56.36.$$

Therefore, when the option is considered, the expected NPV is:

$$E[NPV] = -50 + \frac{0.7(-50)}{1.1} + \frac{0.7(0.8(200) + 0.2(120)) + 0.3(0)}{1.1^2} = +20$$

And the project should proceed.

Figure 5. Abandonment Example, Real Options (Harvey, 1999)

Although this example is simple, it reveals the inherent value of being able to exercise the real option of abandoning a project if the results indicate a loss. In this example, the NPV improves from -\$4.38 to \$20 which would result in the approval of the project. It is also important to recognize that the simplified nature of this example

overlooks the fact that the discount rate of the project would vary since the project is not as risky with the option to abandon under unfavorable market conditions (Harvey, 1999).

Real Options or Decision Tree Analysis

Decision Tree Analysis (DTA) or Decision Analysis (DA) is another of the traditional tools used for the valuation of projects. Copeland and Keenan (1998a) describe DTA as a tree structure depicting all possible states of a project, the probabilities of occurrence for each state, and the decisions management can take in response to these states. The tree is evaluated by discounting the expected cash flows, a function of the probabilities of occurrence, with an appropriately selected discount rate (Copeland & Keenan, 1998a).

An advantage of DTA is its graphical depiction of the project, decision points, and probabilities; which facilitate an ease of explanation and understanding. Unlike DCF, DTA actively assesses the uncertainty of the project life and management's ability to respond to these uncertainties, as depicted in Figure 6. Decision analysis and real options would appear to produce the same results; both methods map out the possible outcomes of the project, accounting for project uncertainty and recognizing management's flexibility to respond to this uncertainty. In this regard, decision analysis and real options valuation are closely related, as decision analysis can lead to options analysis. However, the two approaches differ on the discount rate used for the valuation. Decision analysis uses a constant discount rate for the entire project; while real options adjusts the discount rate at each point of the project (Copeland & Keenan, 1998b). By adjusting the discount rate, the evaluation more realistically accounts for the changes in risk at the various stages of the project (Copeland & Keenan, 1998b).

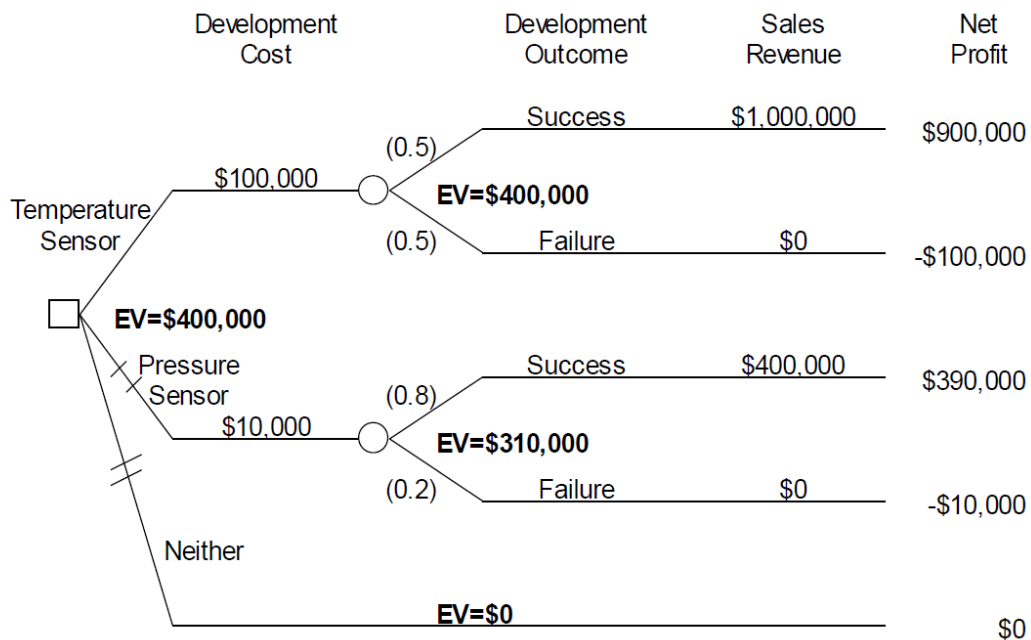


Figure 6. Decision Tree Analysis (Kirkwood, 2002)

Recent Considerations For Real Options

As described, real options provide management with the ability to assess a project's potential value accounting for flexibility and management choices. This assessment requires little insight into the actual technical details of the project, treating the inner workings of the project like a "black-box" (de Neufville, 2003a). This traditional view of real options is described as real options "on," because it strictly evaluates the strategic options (to open, close, delay, etc.) of a project without consideration for the technical aspects of the project (de Neufville, 2003a). This view of real options has progressed as the field of systems engineering has begun exploration of the potential uses of real options in the design of complex systems.

The systems engineering community has recently addressed the concept of real options "in" for evaluating the technical aspects of system design. This option valuation

methodology assumes the perspective of a system engineer versed in the technical details of the project. As such, the valuation focuses on the technical options available for the design of the system. Real options “in” differs from other options because knowledge of the system is required (de Neufville, 2005a). The recent exploration of real options “in” changes the paradigm of system engineering and system design, thereby placing greater value in flexible designs. de Neufville (2005b) asserts that the ability to respond to future uncertainties with flexible designs offers improvements over the traditional approach of design optimization and design to specification.

Real Options in Practice

Real options have been adopted by numerous industries, replacing or supplementing traditional methods of project valuation such as DCF and DTA. Triantis and Borison (2001) noted that many firms are drawn to the notion of real options over concerns of management’s tendency to overvalue, overpay, and over invest in projects or other corporate investments, as these firms are motivated to capitalize on fleeting economic opportunities and establish market leadership positions. In addition to the notion of commonly expressed concerns and motivations, firms using real options share several common traits. These traits have been described by Triantis and Borison (2001), Leslie and Michaels (1997), and Copeland and Keenan (1998b) in their respective studies on the application of real options, and are summarized in Table 4.

Table 4 <i>Common Traits of Firms Using Real Options</i>	
Common Industry Traits	
1)	Investment intensive industries
2)	Large investments with uncertain returns
3)	Traditional valuation models are inadequate
4)	Engineering sciences needing sophisticated analytical tools
5)	Phased developments
6)	Cyclical processes

The early acceptance of real options was markedly slow, as only a few industries implemented this methodology, namely pharmaceuticals and oil and natural gas exploration firms (Mehta, 2005). Early adoption of real options was hampered by its complexity (Mehta, 2005). As firms have become more familiar with the theory and methodology, more have sought to integrate this tool into their practices. The variety and scope of industries and firms currently employing real options has grown and represents a diverse group of firms, as presented in Table 5 (Alleman, 2002; Copeland & Antikarov, 2001; Faulkner, 1996; LCDR Cesar G. Rios, Housel, & Mun, 2006; Triantis & Borison, 2001).

Table 5 *Industries and Firms Using ROM*

Industries	Firms
Consumer and Industrial Products	Dupont, LLBean, Proctor & Gamble, Unilever
Consulting and Financial Services	Credit Suisse First Boston, Morgan Stanley, Stern Stewart & Company
Engineering Services, High Technology and Infocom	Cadence Design Inc, Hewlett Packard, Intel, Kodak, M/A-COM, Motorola, Rockwell, Seagate, Sprint, Ultratech
Life Services, Biotechnology, Pharmaceuticals	Amgen, Genentech, Genzyme, Merck, Pfizer
Energy, Natural Resources	Anadarko, British Petroleum, Chevron, Cinergy, ConEdison, Conoco, Constellation Energy Group, Dynegy, El Paso, Enron, Lakeland Electric, Ontario Power Generation, Peaker-Plants, Shell, Texaco, Wisconsin Public Service Corporation, Xcel Energy
Real Estate, Homebuilding	Beaser Homes
Aeronautics, Automotive, Transportation	Airbus, Boeing, British Airways, Canadian Pacific, General Motors

Real Options Frameworks

As the number of firms employing real options grows, so too does the opportunity to explore different methods of using this strategic management tool. Although initially conceived as a quantitative tool for project valuation, the deployment of real options in organizations has evolved. In a study of 39 organizations, Triantis and Borison (2001) categorized the techniques employed by firms to implement real options as a way of thinking, as an analytical tool, and as an organizational process. The notion of real options as more than an analytical tool is furthered in McGrath's (1999) and McGrath and MacMillian's (2000) description of real options reasoning, which they describe as "a logic for funding projects that maximizes learning and access to upside opportunities while containing costs and downside risk." Luehrman (1998b), Copeland and Antikarov (2001), and Leppard (2001) also describe different quantitative approaches for the

determination of a real options value. Although each approach is based on the works of the Black-Scholes option pricing model, the methods of determination varied.

Luehrman (1998a) describes an option space defined by two metrics, value-to-cost and volatility. These metrics are evaluated using Black-Scholes Option-Pricing model data and graphed to represent option value, such as in Figure 7.

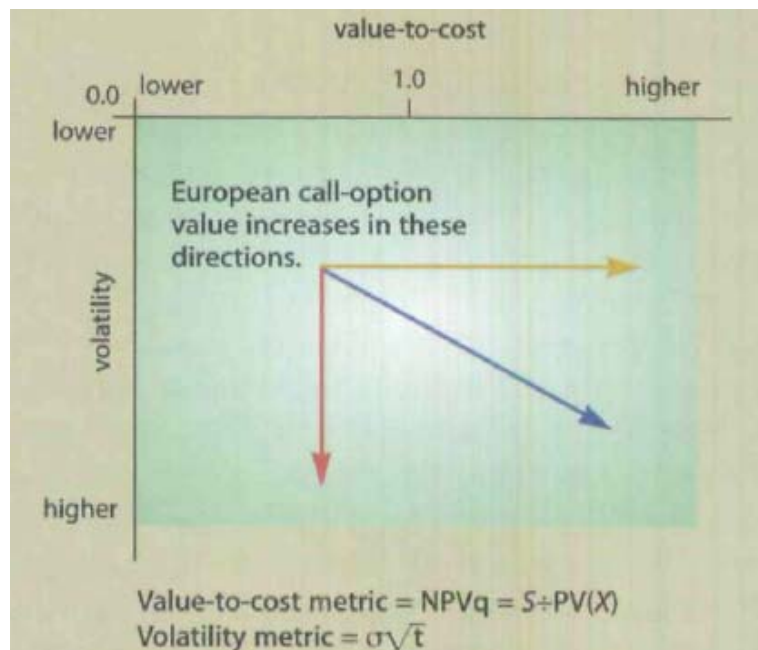


Figure 7. Option Space (Luehrman, 1998b)

Copeland and Antikarov (2001) evaluate option values using binomial and multinomial lattices evaluated with either a replicating portfolio method, as depicted in Figure 8, or a risk neutral probability method. Both of these approaches are derived from practices and calculations used in financial operations to evaluate stock option values.

Leppard (2001) describes a diagrammatic technique for the valuation of fixed assets, defined by a three-dimensional state space for option value. The stated intent of

this methodology is to provide a common ground between analysts and non-mathematical business practitioners for discussing option value. Figure 9 depicts an American “put” option displayed using a diagrammatic approach.

McGrath and MacMillan (2000) present a logic-based framework for the evaluation of technologies. The process involves the use of their Strategic Technology Assessment Review (STAR). The STAR process is constructed around a series of survey questions, which are identified as factors in determining the value of technology options. Each factor depicted in Figure 10 is evaluated with a series of questions using a seven-point Likert scale. The survey question responses are evaluated using STAR to determine the value of the option.

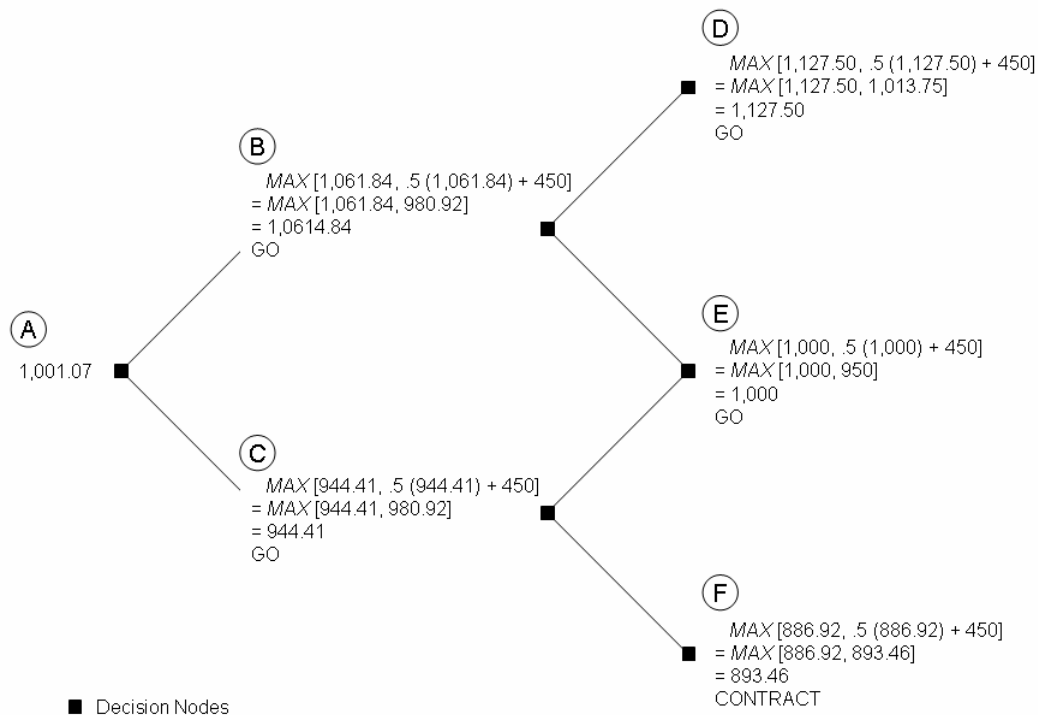


Figure 8. Binomial Decision Tree (Copeland & Antikarov, 2001)

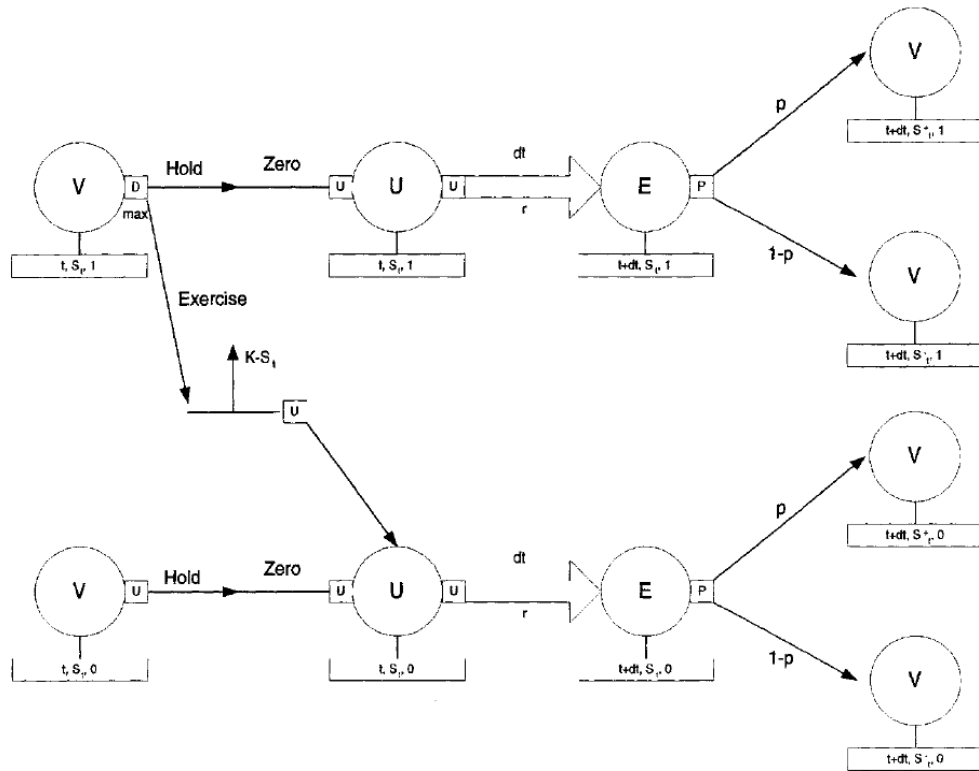


Figure 9. American Put Option Diagram (Leppard, 2001)

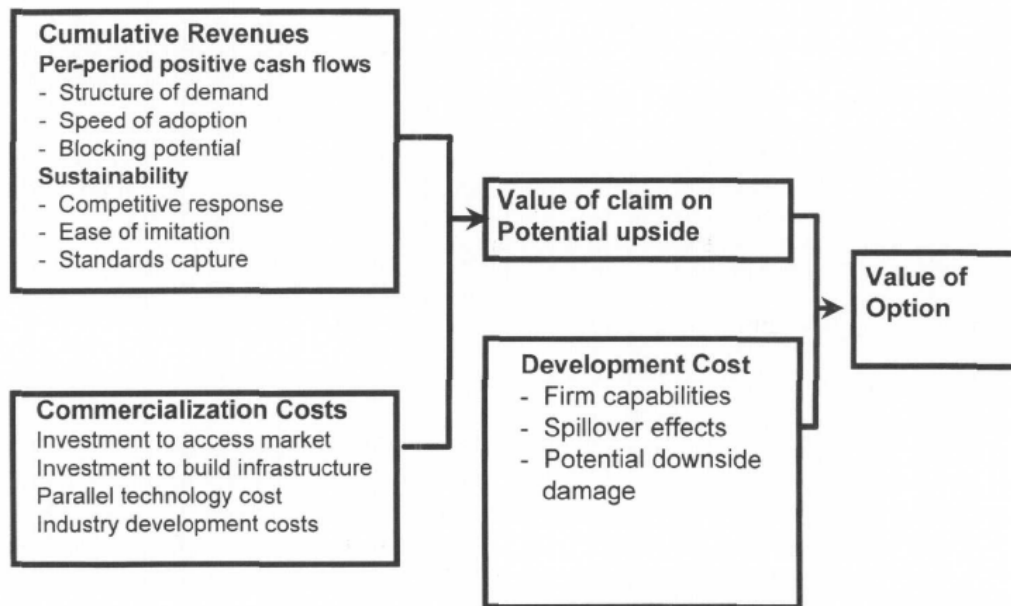


Figure 10. Factors Influencing Technology Option Value (McGrath & MacMillan, 2000)

Practical Limitations to Real Options

Real options provide a powerful alternative to the traditional means of project valuation. However, there are limitations; as Professor Stewart Myers once stated, “quantification of option value can be quite difficult” (Mehta, 2005). This is particularly true for large projects with numerous options; as the number and combination of options grow, so to does the complexity of the option valuation (Kemna, 1993).

Additionally, the uncertainty of the underlying project is difficult to determine (de Neufville, 2003b; Kemna, 1993). In financial options, there is extensive statistical history to evaluate in order to determine the options uncertainty. However, with projects there is generally little historical precedent to rely upon to generate an appropriate measure of uncertainty (de Neufville, 2003b).

Real Options in the Federal Government

Despite these limitations, an increasing number of firms have explored the subject of real options (Sammer, 2002; Triantis & Borison, 2001). Organizations within the federal government have also explored the utility of real options, to include the Navy and National Aeronautics and Space Administration (NASA) (Davis, 2003; Gregor, 2003; LCDR Cesar G. Rios et al., 2006; Shishko, Ebbler, & G., 2003). The Navy’s examinations of real options have included analysis of real options in systems design and as a management framework for its Information Technology (IT) portfolio management efforts.

Gregor’s (2003) research in the ocean engineering department at MIT was motivated by the need to design ships to contend with the uncertainty of changing

missions, threats, and technologies. Gregor (2003) utilized the concepts of real options “in” to identify and evaluate the options available for the design and acquisition of a new naval ship. Gregor (2003) concluded that analytical methods of real options could be applied, with many assumptions, to the design and acquisition of naval ships in the public sector, although not with the same certainty of a financial options.

The Navy has also conducted research into the application of real options for management of its IT Portfolio, employing real options as a management tool for future investments (Davis, 2003; Rios, Housel, & Mun, 2006). Davis (2003) identified that the Federal Chief Information Officer (CIO) endorsed the use of IT Portfolio Management (ITPM) for the management of IT investments. He further noted that the use of ITPM relied upon traditional methods of investment valuations, such as NPV, Earned Value Analysis (EVA), and Internal Rate of Return (IRR); and proposed real options as an alternative methodology. Davis (2003) concluded that the use of real options offered an alternative tool for investments involving uncertainty without significantly expanding the information requirements or administrative needs. Rios et al., (2006) also investigated the use of real options for ITPM. Specifically, they examined the Knowledge Value Added/Real Options (KVA+RO) valuation framework for use in an integrated portfolio analysis for Intelligence Information systems (Rios et al., 2006). They concluded that the KVA+RO framework offered a “powerful” tool for use within governments and corporate industries (Rios et al., 2006).

NASA has also explored the concept of real options for technology assessment. NASA’s efforts focused on the use of the real options methodology in evaluating and providing design choices for technology for satellite and space systems (Shishko et al.,

2003). In their examination, NASA employed a modified version of the Black-Scholes model tailored to address the unique aspects of their technology projects..

The Office of Force Transformation (OFT) has also espoused the benefits of real options for use in defense, suggesting that tools such as the Programming, Planning, and Budgeting System (PPBS) and the Future Years Defense Program (FYDP) are inadequate for the current and future security environment (Glaros, 2003). Glaros (2003) specifically noted that the needs in defense are not significantly different from those of the commercial marketplace, “mitigation of risk by hedging against uncertainty, brought about by rapid dynamics changes.” In the context of the defense environment, Glaros (2003) suggested that real options add strategic value by providing alternative courses of action for decision makers, such as designing requirements based on the value of flexibility. Glaros (2003) suggested that a real options framework has significant value for leadership within the acquisition system, in light of the development cycles of acquisition programs, by providing the flexibility to cancel or defer projects at any stage to mitigate risk and increase potential. The concept of real options has also prompted the consideration of alternative strategies for defense investments. The former director of OFT, Admiral Arthur Cebrowski, identified such opportunities to the Armed Services Committee in his comments on strategic forces:

As we move towards the age of the small, the fast and the many, it's time to start thinking about applying that movement to our model for space. Adopting this complementary and broader business model will help us ensure space superiority well into a future where space will be yet more responsive to our joint military forces. In short, it is within our capability to create options, a process which itself can be a competitive advantage.

The intent and results of these efforts and comments demonstrate the utility of a real options framework for the Department of Defense (DoD). However, as proposed by Ceylan and Ford (2002), implementation of an options framework for defense acquisition requires a structured approach for the description, design, assessment, and use of options based on current practices. This proposed implementation would require policy and guidance necessary to integrate it into the acquisition framework.

DoD Acquisition Framework

The current acquisition framework is governed by three distinct, but interrelated, processes as described by the Defense Acquisition Performance Assessment (DAPA) report (DAPA, 2006). The Joint Capabilities Integration and Development System (JCIDS) process governs the generation of requirements and the determination of the best means to satisfy these needs. The defense acquisition system describes the acquisition framework for executing the procurement and modification of weapon systems. Finally, the Programming, Planning, Budgeting, and Execution (PPBE) system authorizes, appropriates and manages the resources necessary for the execution of the requirements and acquisition processes. The DAPA report defines the interaction of these processes as the big “A,” Acquisition System (DAPA, 2006).

Joint Capabilities Integration And Development System

The JCIDS process as deployed by Chairman of the Joint Chiefs of Staff (CJCS) is described in CJCSI 3170.01E. The JICDS process is described as a “joint concepts-centric capabilities identification process” to prioritize and identify the capabilities required by the joint forces (CJCS, 2005). The process is intended to be top-down,

linking the National Security Strategy to the requirements and capability needs of the joint forces, as displayed in Figure 11.

JCIDS is a collaborative and capabilities-based process, employing joint concept of operations to define and prioritize capability gaps and determine the means to resolve these capability gaps. The process involves functional analyses and identification of needs in the context of existing Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF) and determines whether resolution of these needs requires a materiel or non-materiel solution; or a change to DOTMLPF. The identification of a materiel solution initiates action in the acquisition system to develop and acquire the solution.

Defense Acquisition System

The acquisition system is governed by DoDI 5000.1, The Defense Acquisition System, and by DoDI 5000.2, Operation of the Defense Acquisition System. These documents define the intent of the acquisition system which is to be flexible, responsive, innovative, disciplined, streamlined, and effective in the execution of a system's acquisition (USD(AT&L), 2003a). These documents also deploy the defense acquisition management framework, which defines the key decision milestones and execution phases for pre-systems acquisition, systems acquisition, and sustainment, as displayed in Figure 12. This framework is managed by the Milestone Decision Authority (MDA), the individual with overall program responsibility and authority; and the Program Manager (PM), the individual appointed to execute the program. The milestones represent checkpoints for the MDA to evaluate progress and determine whether a project continues to a subsequent phase (USD(AT&L), 2003a). The phases represent different stages of a

program's development, from concept initiation to system retirement. The execution of program phases is managed by the PM.

Essential additions to this management framework are the concepts of evolutionary acquisition and spiral development. Evolutionary acquisition is a strategic process for the incremental delivery of capability, balancing the needs of the user and the resources available to satisfy those needs – stressing rapid and iterative delivery of increasing levels of capability (USD(AT&L), 2003b). Spiral development is the means to achieving an evolutionary capability; in which requirements are identified but the end-state of the program is not defined, allowing for iteration with the user throughout the program's development (USD(AT&L), 2003b).

Programming, Planning, Budgeting and Execution

The PPBE system is designed to generate a plan, as well program and budget for DoD programs and initiatives. It is a cyclical process operating in two-year cycles, which allows for the planning of future efforts and the review of on-going efforts in the context of the current environment (ASD(C), 1984). This decision making framework provides the DoD with a means to plan, program, budget, and execute investment strategies. The resources appropriated by the PPBE are defined by the DoD Financial Management Regulation 7000.14-R.

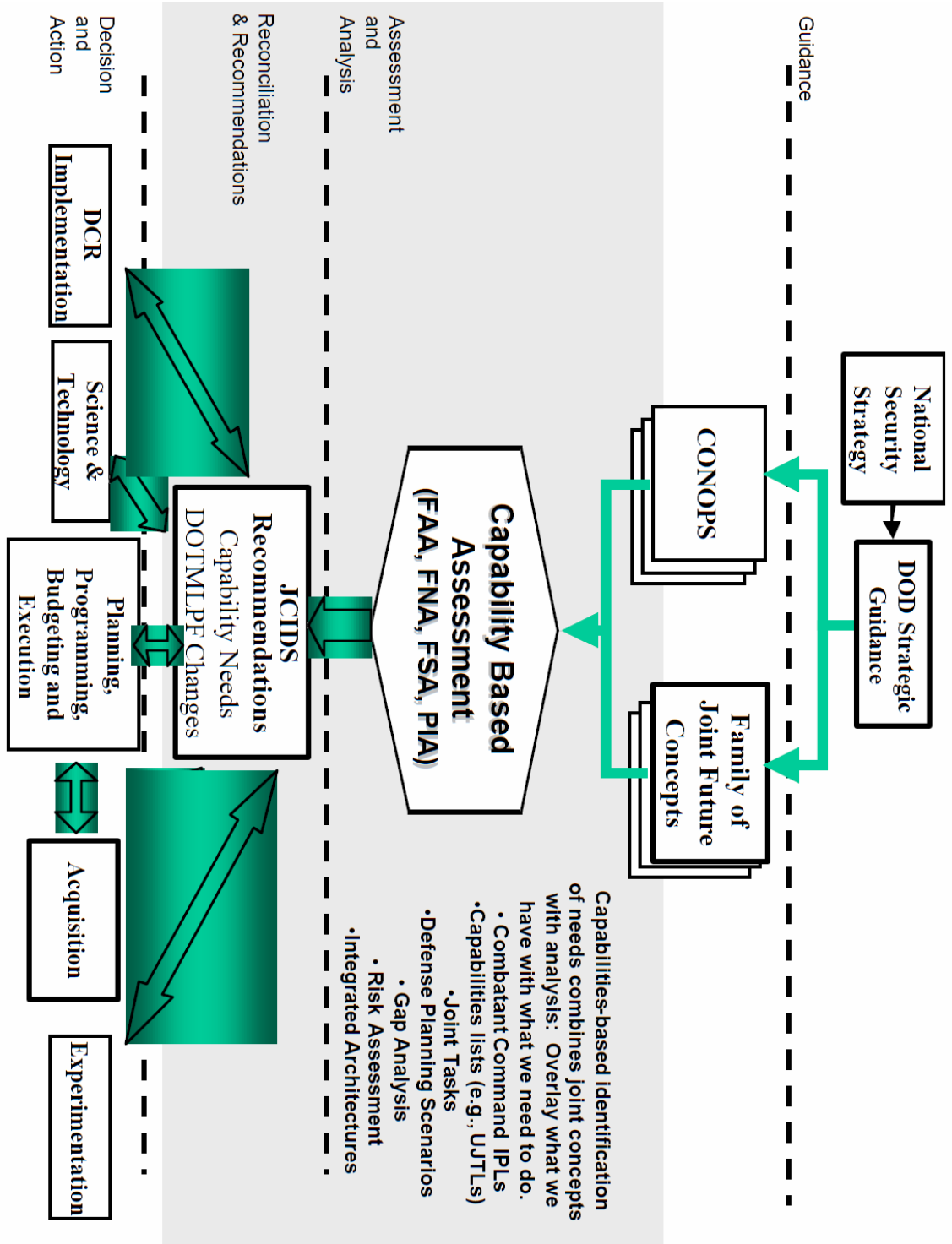


Figure 11. Top Down Capability Need Identification Process

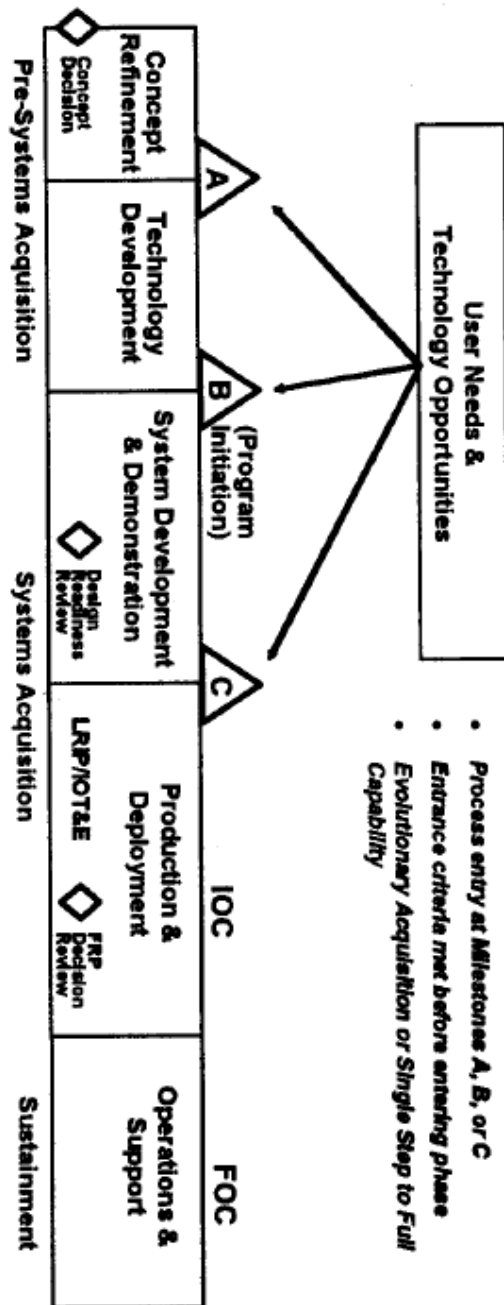


Figure 12. Defense Acquisition Management Framework (USD(AT&L), 2003b)

The principal fund types appropriated for DoD acquisition programs are Research, Development, Test and Evaluation (RDT&E); Procurement; and Operations and Maintenance (O&M) (Carroll, 2003). Each fund type must be obligated and expended within a specified timeframe, governed by the fund type and the date of obligation, as presented in Table 6. Any funds that are not obligated within the specified time expire and any funds not expended within the specified time are canceled (Carroll, 2003).

Table 6 DoD Fund Types and Execution Requirements (Carroll, 2003)

Budget Execution	Appropriation Type			
	RDT&E	Procurement	O&M	Military Construction
Obligation	2 Yrs	3 Yrs	1 Yrs	5 Yrs
Expenditure	5 Yrs	5 Yrs	5 Yrs	5 Yrs

Defense Acquisition Performance Assessment

In June 2005, Gordon England, Acting Deputy Secretary of Defense, chartered the DAPA project to develop an action plan for transforming the acquisition system. Reacting to the continued concern of cost overruns, schedule delays, and the urgent need to provide a system responsive to the demands of the 21st century, he initiated a “carte blanche” assessment to review and improve the defense acquisition processes (DAPA, 2006). In his memo to the members chartered to lead the DAPA project, Secretary England established the trade space to be considered in the review and recommendations. He authorized a comprehensive assessment considering all aspects of the acquisition process: requirements, organization, legal foundations, decision methodology, oversight, and checks and balances (DAPA, 2006).

The DAPA project represented the first comprehensive and integrated assessment of the acquisition process, exploring the budgeting processes, the requirement processes, and the acquisition processes in total. The charter of the DAPA project was to provide the recommendations needed for the radical transformation of the acquisition system to better operate in the new security environment of the 21st century. The goal of the study was to construct an integrated acquisition system able to deal with the unstable external climate, the rapidly evolving security environment, and the need to be agile and flexible in the face of a wide spectrum of potential conflicts (DAPA, 2006).

The DAPA panel members described the big “A” Acquisition System as the integrated framework of the JCIDS process, the acquisition management framework, and the PPBE (DAPA, 2006). With this construct, the DAPA panel members suggested that the activities of any acquisition effort are governed by the interaction of this big “A” framework. To that end, the panel members asserted that the framework is fragmented, being pulled apart by conflicting interests and competing values as depicted in Figure 13 (DAPA, 2006).

The DAPA panel built upon this framework to shape the context of the deficiencies of the acquisition system. Within this context, the panel members provided a set of comprehensive recommendations, addressing critical areas for improvements in each element of the Acquisition System framework. The recommendations from the DAPA panel members addressed organization, workforce, budget, requirements, acquisition, and industry, as described in Figure 14. These recommendations represent the potential for a significant departure from the norms of the acquisition system.

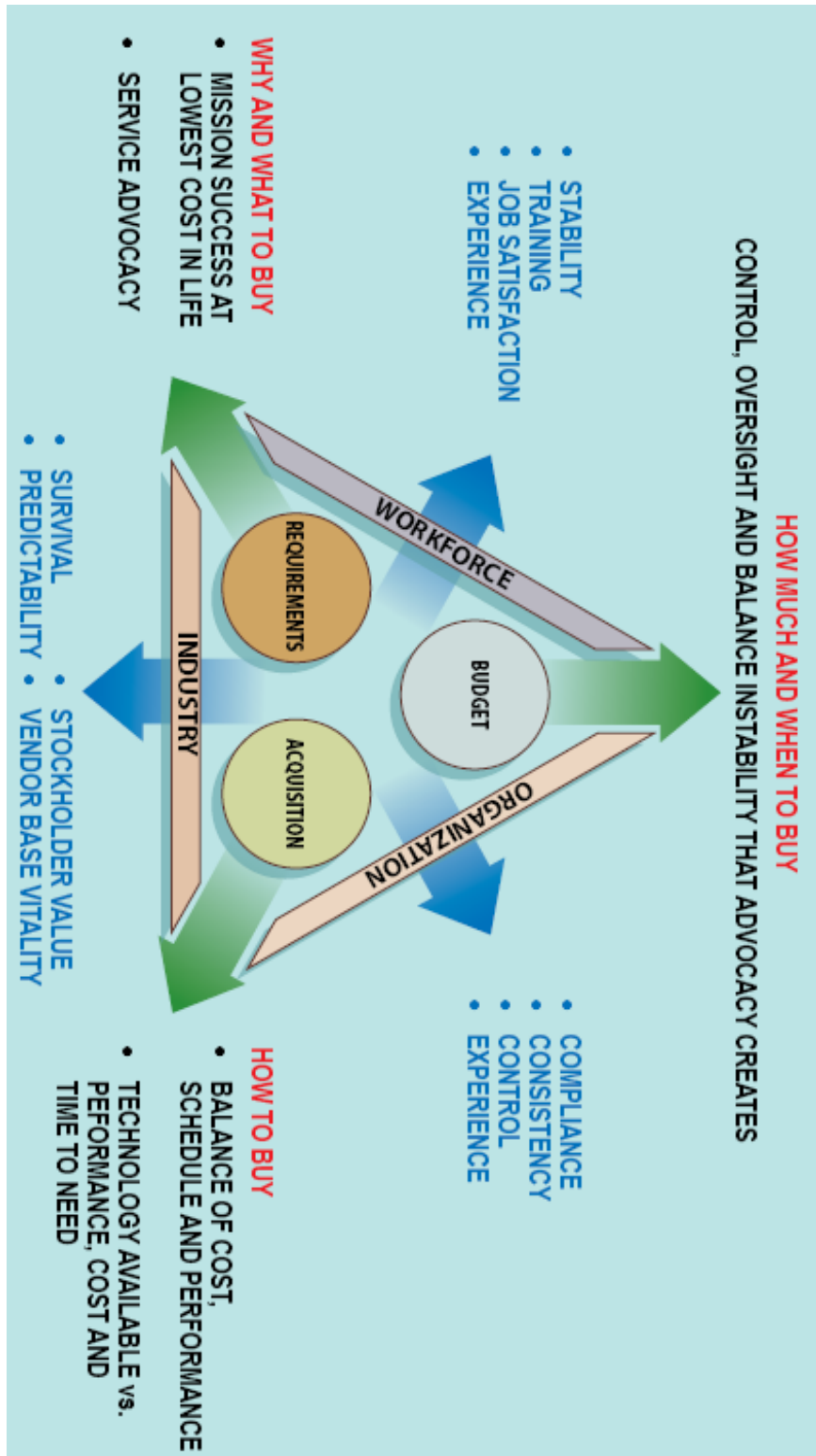


Figure 13. Acquisition System Framework (DAPA, 2006)

Organization

- Realign authority, accountability and responsibility at the appropriate level and streamline the acquisition oversight process.
- Establish dedicated Four-Star Acquisition Systems Commands, at the Service level.

Workforce

- Rebuild and value the acquisition workforce, and incentivized leadership.

Budget

- Transform the Planning, Programming and Budgeting process and establish a distinct Stable Program Funding Account.

Requirements

- Replace the Joint Capability Integration and Development System with the Joint Capabilities Acquisition and Divestment Plan (a Combatant Commander-led requirements process in which the Services and Defense Agencies compete to provide solutions.)
- Establish a two-year recurring process to produce an integrated, time-phased and fiscally-informed Joint Capability Acquisition and Divestment plan and a continuous Materiel Solutions Plan Development Process to identify and initiate development of Materiel Solutions
- Add an “Operationally Acceptable” test evaluation category.
- Give program managers explicit authority to defer non-Key Performance Parameter requirements to later spirals or block upgrades.

Acquisition

- Adopt a risk-based source selection process.
- Shift to time-certain development procedures and make schedule a Key Performance Parameter.
- Mandate a time start and end dates that are clearly defined and revamp the acquisition processes to support it.

Industry

- Overcome the consequences of reduced demand by sharing long range plans and restructuring competitions for new programs.
- Require government insight and favor formal competition for major subsystems when a Lead System Integrator acquisition strategy is pursued.

Figure 14. DAPA Report Recommendations: Budget, Requirements, Acquisition

Summary

This chapter reviewed the history and current state of practice for real options. The review addressed the merits of real options over other traditional project valuation methods. A discussion was also offered of the various frameworks used in the application of real options. The defense acquisition system framework was also reviewed to provide a context for the application of a real options methodology. Finally, a discussion was offered on the changes necessary for change as recommended by the DAPA panel. The following chapters will address the methodology, results and conclusions of this study.

III. Methodology

Introduction

The focus of this research was a case study of the Operationally Responsive Space (ORS) initiative and the Tactical Satellite (TacSat) experiments. ORS is a transformational initiative being undertaken by the DoD Office of Force Transformation (OFT) to demonstrate a systems architecture for providing flexible and responsive tactical satellite capability for the Combatant Commanders (COCOMs) and their forces at the operational and tactical level of combat. To demonstrate this capability, several tactical satellite (TacSat) experiments are being conducted to demonstrate technologies and concepts identified in the ORS vision.

This case study examined the strategy and execution of this initiative in the context of a real options framework. In particular, the study focused on elements of the ORS initiative that identify opportunities for flexibility in the acquisition system. The objective of this research was to qualify the opportunities, benefits, and challenges for the implementation of flexibility in the ORS initiative and present observations for the application of similar levels of flexibility in the acquisition system framework.

This chapter addresses the case study design and application of the case study protocol. The review will cover the rationale for the design, the methods of data collection, and the procedures for analyzing the data. Finally, an overview of the ORS initiative and the TacSat experiments provide background information for the case study.

Research Objectives

Given the DoD's recognition of the highly uncertain security environment of the 21st century and the need for responsiveness and flexibility in its processes and operations, the systematic framework of real options offers a potential tool to addresses these needs. As suggested by Glaros (2003), the DoD stands to gain substantial benefit from the implementation of a real options framework. This notion is further supported by the proposition presented by Copeland and Keenan (1998a) that organizations operating in a highly uncertain environment and executing with a high degree of managerial flexibility may realize additional value from the real options methodology. Based on these observations, this research explores the potential for implementing a real options framework for the DoD acquisition system. The proposed framework considers the approaches to implementing real options as examined by Triantis and Borison (2001): as a way of thinking, as an analytical tool or as an organizational process.

The intent of this study is to explore the opportunities to apply this real options framework to an acquisition system. The primary research question for this study is: “What are the opportunities for implementing a real options framework within the DoD Acquisition System?” The secondary research questions are as follows:

- How can the acquisition system apply a real options framework?
- How can the acquisition system benefit from a real options framework?
- What are the challenges to effectively implementing a real options framework?

Case Study Design

The purpose of this case study was to examine the enabling components of the ORS initiative and the TacSat experiments, such as stakeholders, program structure, and institutional processes, to identify elements within the program exhibiting flexibility or favorable to the implementation of flexibility. To conduct this study, an exploratory, single-case design was chosen. There were three items considered in selecting this method of study, the type of questions asked, the type of case study, and the choice of study design.

The primary consideration in the design of the study method was the type of questions being studied. Yin (2003) suggested that case studies are most appropriate for studies addressing “how” and “why” questions, although there is latitude for “what” questions. As the primary and secondary research questions for this study focus on both “how” and “what” questions, the researcher initially considered the choice of a case study approach to be a valid decision. However, Yin (2003) also suggested the components that guide the choice of study methods also consider the amount of control over environmental behavior and whether the study is historical or contemporary. Although not initially considered when evaluating the research method, the contemporary nature of the case study subject and the environment in which it was conducted both conform to the components identified. As the components and focus of this study correspond with those identified by Yin (2003), the selection of a case study design was judged to be a valid choice.

The second consideration in the design was the type of case study to be conducted. Yin (2003) identified three types of case studies: descriptive, explanatory,

and exploratory. Descriptive case studies attempt to describe a theory, covering the study subject extensively (Yin, 2003). Explanatory case studies attempt to identify a causal relationship regarding the subject of study and certain factors (Yin, 2003). Exploratory case studies involve areas of study where there is uncertainty or there is little information available on the subject (Yin, 2003). An exploratory case study was chosen because very little literature or data exists on the subject of real options in the DoD.

The final consideration was the choice of a multiple or single case design. A single case design was chosen for this study because of the investigational nature of the ORS initiative and the TacSat experiments. Yin (2003) identified five circumstances when a single-case is valid:

- 1) the case is a critical case for proving a well-formulated theory;
- 2) the case is an extreme or unique case;
- 3) the case is typical;
- 4) the case is revelatory and provides an opportunity to observe a previously unobserved event;
- 5) the case is a longitudinal case.

As there are currently no comparable acquisition efforts, the ORS initiative offers the opportunity to observe new strategies and philosophies for the acquisition system; as such, the choice of a single-case was judged to be valid.

Information Source

The two sources of data utilized for this case study were artifacts and interviews. The artifacts available for this study consisted of program documentation on the ORS initiative and the TacSat experiments. The available documentation included items such as the 2007 National Defense Authorization Act, Congressional Hearing reports, American Institute of Aeronautics and Astronautics (AIAA) conference papers, and drafts of the 120-Day Operationally Responsive Space Study. The focus of the artifact data review was the identification of strategies and goals related to the premise of flexibility in systems and processes.

Interview data was provided by Captain Jason Bartolomei from his research on “Dynamic Utility in Design.” The interview data consisted of interview transcripts for several interviews and the investigative questions used for the interviews. The interviews were conducted with six subjects from the OFT and the AFRL TacSat program. The six subjects interviewed had extensive knowledge on the goals and strategies of the ORS initiative. The subjects were recognized leaders involved in the development of the ORS initiative or members actively responsible for its execution. Each subject offered insights from a position of authority or accountability. The objective of the interviews was to identify areas conducive to the implementation of real options or presently exhibiting similar tenets of flexibility, by exploring the enabling elements of the ORS initiative, such as processes, organizational structure, and stakeholder relationships.

The form of the investigative questions for the interviews was well structured; however, the results of the interviews were atypical of what would have been expected. The form and structure of the transcripts were general discussions, as opposed to the

question-response interactions, which were not as well focused as the investigative questions would suggest. In total, 261 pages of discussion transcripts were provided, covering the conversations with each of the six subjects.

Interview Data Analysis

The interview transcripts consisted of five structured interviews conducted with personnel involved in the ORS initiative. A total of six participants were selected from the OFT and the AFRL TacSat program. The personnel who participated in the interviews were identified as members with a clear knowledge of the strategy and goals of the ORS initiative and an exhaustive understating of the TacSat experiments.

The interviews consisted of a series of open-ended discussions. The interviews were guided by a series of investigative questions focused on nine categories of interest and several additional key questions. The investigative questions were provided to the interview subjects in advance of the interviews to allow the subjects to familiarize themselves with the focus of the research and prepare for the actual interviews. The interviews were subsequently conducted as free-flowing discussions guided by the intent of the investigative questions. This free-flowing nature was captured in the interview transcripts, as the transcripts were structured like the flow of a discussion and less like a question-answer investigation.

The overall objective of the interviews was to explore the ORS framework and identify opportunities to implement the concepts and methodologies of real options. The interviews with the subjects from the OFT focused on the strategy, goals, and intent of the ORS initiative with a specific focus on the concept of flexibility and responsiveness

in the acquisition processes. The interviews with the subjects from the TacSat programs focused on the requirements, expectations and execution of the tactical experiments; they provided extensive insight into the technical details of each experiment.

Investigative Questions

Seventy-nine questions were developed by the original Captain Bartolomei to investigate the use or potential application of real options. The questions were grouped into nine specific categories: system stakeholders, organization, system objectives, system activities, engineered system, system drivers, acquisition strategy, contract strategy, and program execution. An example of the types of investigative questions asked regarding system drivers is provided in Table 7. The full list of investigative questions is given in Appendix 1.

Table 7 Sample Investigative Questions

System Driver Questions
1) What are the factors beyond your control have the greatest impact on the system objectives?
2) What are the factors beyond your control have the greatest impact on the organization?
3) What are the factors beyond your control have the greatest impact on the engineered system?
4) What are the factors beyond your control have the greatest impact on the activities?
5) What is the nature of these interactions?
6) How rapidly is the technology supporting the system changing?
7) How have the operational requirements for the system changed, likely to change?
8) What was the impetus of these changes?
9) What are your greatest cost risks? Schedule risks? Performance risks?
10) What do you consider the greatest impediments to your program's success? (FAR, Cost Instability, Organization)
11) What do you consider the greatest enablers?

The researcher identified specific themes in each category of questions and further segregated the questions into three themes. The themes were social interactions, systems engineering and systems acquisition. The organization of the investigative question themes and categories is presented in Table 8.

Table 8 Themes and Categories for Investigative Questions

Social Interaction	Systems Engineering	Systems Acquisition
Organization	System Objectives	Acquisition Strategy
System Stakeholders	System Activities	Contract Strategy
	Engineered System	Program Execution
	System Drivers	

Interview Data Analysis

The analysis of the interview transcript data involved qualitative methodologies for data reduction and data analysis. To reduce the data, the interview transcripts were reviewed for statements related to the primary research question for this study. As the form of the interview data was very open-ended, the review process was iterated several times to properly capture those comments relating to this research. Once the statements related to the primary research question were identified, another level of review was conducted to determine how, or if, the identified responses related to any of the secondary research questions. The result of this review was a categorization of responses related to the applicable secondary research question. Each of these responses was further reviewed to identify common themes amongst the responses. These themes were evaluated in the context of opportunities to implement real options, benefits of real options, and challenges to the implementation of real options.

Program Overview

The following section provides a brief overview of the ORS initiative and the TacSat experiments. The intent is to establish the context for the initiative and experiments.

Overview of Operationally Responsive Space

In 2003, the Secretary of Defense initiated the Operationally Responsive Space (ORS) initiative. The intent of the ORS initiative was to develop an affordable, rapid reaction capability for space, optimized to support theater operations, surge, asset reconstitution, augmentation of national assets, and support to global strike. The goal of ORS was subsequently codified by Congress in Section 913 of Public Law 109-364, as described in Table 11 ("National Defense Authorization Act of 2007," 2006).

Table 9 *FY2007 National Defense Authorization Act*
("National Defense Authorization Act of 2007," 2006)

SEC. 913. OPERATIONALLY RESPONSIVE SPACE

(a) UNITED STATES POLICY ON OPERATIONALLY RESPONSIVE

SPACE.—It is the policy of the United States to demonstrate, acquire, and deploy an effective capability for operationally responsive space to support military users and operations from space,

which shall consist of—

- (1) responsive satellite payloads and busses built to common technical standards;
 - (2) low-cost space launch vehicles and supporting range operations that facilitate the timely launch and on-orbit operations of satellites;
 - (3) responsive command and control capabilities; and
 - (4) concepts of operations, tactics, techniques, and procedures that permit the use of responsive space assets for combat and military operations other than war.
-

The ORS concept was conceived as a transformational effort to address the conflict between the operational utility and global utility of national space assets. The

conflict exists in the execution and prioritization of high demand national satellite systems, as these systems are tasked to support national, strategic, operational, and tactical objectives. ORS proposes a strategy to addresses these conflicts with a flexible and responsive architecture capable of meeting the urgent needs of the operational and tactical levels of combat.

The transformational strategy for ORS specifies two objectives: responsiveness to the tactical and operational levels of combat, and anticipation of rapid changes in threats and technologies (OFT, 2006). The elements of ORS strategy for achieving these goals are operational experimentation and execution. Operational experimentation is the pairing of developmental technologies to operational concepts and the demonstration of these pairings in an operational environment. Operational experimentation focuses the development of technologies on the needs of the joint warfighter and enables the evaluation of technologies before greater commitments are made. Execution establishes the means for the rapid acquisition of low cost and relevant capabilities. Execution is described as a joint effort between the services, Combatant Commanders (COCOMs), laboratories, academia, and industry (OFT, 2006).

Tactical Satellite Experiments

The OFT initiated the TacSat experimental programs to demonstrate the core concepts of ORS. The TacSat experiments employ co-evolutionary design techniques, as depicted in Figure 15. This framework allows for the evaluation of learning options on disruptive technologies and the refinement of technologies, concepts, and processes as the experiments evolve. The objective of this approach is to hone the facets of ORS through the TacSat experiments, so that the results can influence “technology, policy,

concepts of operations, acquisition processes and public/private partnerships” (*Statement of Arthur K. Cebrowski Director of Force Transformation Office of the Secretary of Defense, 2004*).

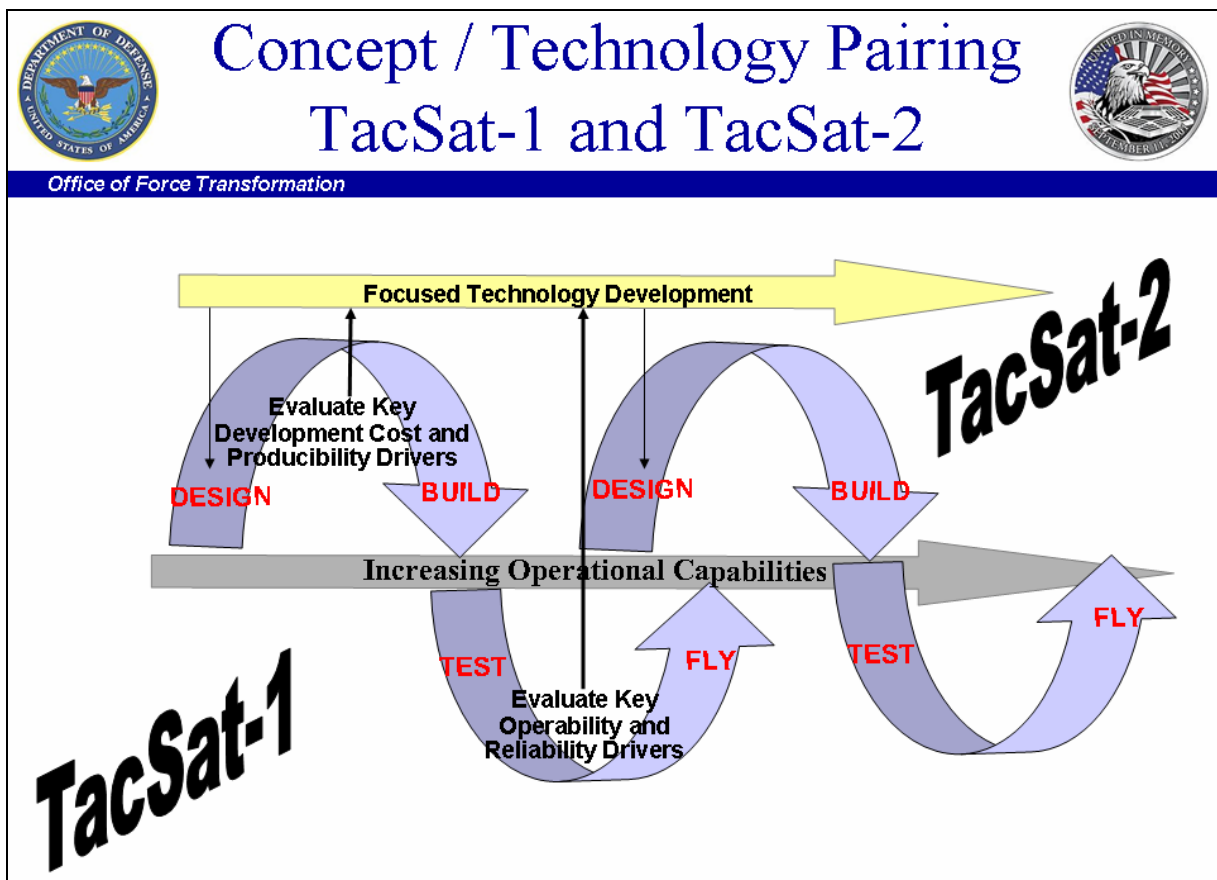


Figure 15. Co-Evolutionary Strategy (OFT)

Four TacSat experiments have been planned as elements of this co-evolutionary strategy. The goal of each TacSat experiment is to evaluate potential technologies and concepts and to conduct operationally representative demonstrations. The highlights of each experiment are listed in Table 12. Each TacSat experiment is designed to address the broader system characteristics and design philosophies being explored by ORS:

operationally relevant, automated micro-satellite bus, modular payloads, common interfaces, SIPRNET dissemination, low-cost, and rapid-response launches.

Table 10 *TacSat Experiments*

Experiment	Objectives	Organization
TacSat-1	<ul style="list-style-type: none"> • Dual-mode target identification using Specific Emitter Intelligence (SEI) 	NRL for SD/OFT
TacSat-2	<ul style="list-style-type: none"> • MSI designed/built spacecraft bus • Provides SEI, Automatic Identification Systems & 1m optical resolution imagery directly to tactical user 	AFRL/VS
TacSat-3	<ul style="list-style-type: none"> • 7-day call-up to launch • Hyperspectral and panchromatic Imagery directly to tactical user 	AFRL/VS
TacSat-4	<ul style="list-style-type: none"> • “Comm on the move”, Data exfiltration and Blue Force tracking • Provides communication augmentation to soldiers in theatre 	NRL

Summary

This chapter reviewed the research questions for this study, detailed the method for conducting a case study to address the research questions, and addressed the methods used for analyzing data collected for the case study. The discussion of data analysis provided insight into how the results of this study were achieved. Details regarding the results, conclusions, and recommendations will be presented in Chapter IV, Results, and Chapter V, Conclusions and Recommendations. Finally, an overview of the ORS initiative and the TacSat experiments was provided to offer insight and background on the goals of the initiative and the means to achieving the stated goals.

IV. RESULTS

Introduction

This chapter reviews the results of the case study on the Operationally Responsive Space (ORS) initiative and the efforts of the Tactical Satellite (TacSat) experiments. The first section details the qualitative approach used for interview data analysis and presents the initial results of categorizing responses and the identification of response themes. The second section presents the results of the interview data analysis. The results detailed will include the major themes identified within the interview responses, how these themes relate to the secondary research questions, and insights into the predominant themes identified in the interview responses.

Interview Data Analysis

The analyses of the interview transcripts required a qualitative mechanism to extract, group, and organize relevant data. To conduct this qualitative analysis, the researcher referenced the methods of grounded theory presented by Glaser and Strauss (1967) and the processes for qualitative analysis presented by Miles and Huberman (1994). These methodologies provide a means for the evaluation and examination of qualitative data to identify themes and patterns as governed by the goals of the research (Miles & Huberman, 1994).

The content of the interview transcripts were first reviewed to identify comments and insights relating to the primary research question, identifying elements of the ORS initiative and TacSat experiments amenable to the implementation of real options or

presently exhibiting tenets of real options. Specific interest was placed on identifying comments regarding the execution of flexible strategies, processes, and flexibility in systems design. The initial analysis of the interview data identified 140 comments and insights related to the goals of this investigation. These insights were evaluated to identify those comments and insights with the strongest correlation to the research questions. This evaluation eliminated 37 responses judged to be low in correlation to the research questions. The final results of this effort were 103 responses identified as relevant to the intent of the research questions.

The responses captured in these initial efforts were subsequently reviewed and associated with the secondary research questions. The intent was to group the comments and insights by the degree to which they addressed a particular secondary research question. The process of relating these insights to the research questions yielded the results depicted in Table 11.

Table 11 *Number of Related Responses*

Secondary Research Questions	No. of Related Responses
How can the acquisition system apply a real options framework?	35
How can the acquisition system benefit from a real options framework?	24
What are the challenges to effectively implementing a Real Options framework?	44

Once the responses were matched with a research question, they were reviewed to identify patterns and themes. The patterns observed in the responses were identified as themes relating to the implementation, benefits, or challenges towards a real options framework. Responses not fitting a particular pattern were also classified as a theme,

with a response size of one. The results of pattern matching and theme identification are depicted in Table 12.

Table 12 *Response Themes*

Secondary Research Questions	Identified Themes
How can the acquisition system apply a real options framework?	5
How can the acquisition system benefit from a real options framework?	7
What are the challenges to effectively implementing a Real Options framework?	11

Structured Interview

This section addresses the analysis of transcript data from structured, open-ended interviews conducted with members of the OFT and the AFRL TacSat program. The objective of the interviews was to identify areas conducive to the implementation of real options or presently exhibiting similar tenets of flexibility, by exploring the enabling elements of the ORS initiative, such as processes, organizational structure and stakeholder relationships. The review also sought to identify potential limitations or impediments to the execution of a real options framework. The following discussions will review the major themes discovered within these transcripts during analysis

Secondary Research Question #1 Observations

The first question, “how can the acquisition system apply a real options framework,” focused on identifying opportunities within the acquisition system to implement flexibility as described by the real options. In this context, flexibility is the ability to efficiently implement change. Opportunities within the acquisition system include, but are not limited to, organizational culture, organizational structure, policies,

and processes. The analysis of the interview transcripts identified 38 responses related to the first study question. A review of these responses identified five common themes, as presented in Table 13. Of these five themes, the majority of the responses were related to the themes of: an alternative business strategy, flexible response to future events, and flexibility in system design.

<i>Table 13 Opportunities for Real Options</i>	
Themes Relating to Opportunity	
1.	Alternative Business Strategy
2.	Flexible Response To Future Events
3.	Risk Analysis
4.	Management Framework
5.	Capitalize On Emerging Capabilities

Alternative Business Strategy

Discussions relating to the theme of an “alternative business strategy” identified two focus areas: recognized deficiencies within existing processes and how a flexible system would provide a better model, as presented in Table 14.

Two respondents commented on the elements within the acquisition system process, the PPBS, and the acquisition policies, identifying them as unresponsive and inflexible. One respondent described the PPBS as being slow and outdated. The respondent reflected on the fact that the system was designed during the cold war and evolved appropriately to counter the threat of the Soviet Union. However, the system is incapable of meeting the needs of the current acquisition environment. The respondent specifically noted that:

McNamara's model which was of the right thing to do at the time, is now crumbling under the rate of the increasing speed of the marketplace and the lower barriers to competition in that marketplace.

Table 14 *Alternative Business Strategy*

Response Summaries
<ul style="list-style-type: none"> • Existing model too slow for current market place • Current acquisition policies are prescriptive and limit flexibility • Value assessment input for POM • Determine strategic force mix • Invigorate Congress with new business strategy • ORS offers business model for operations and system acquisition • Gain flexibility through common standards accepted by industry • Develop systems/architecture to allow for future flexibility and new technologies • Process that responds to "user" market • Decision analysis for cost vs. capability trades • Technology risk reduction for large satellite development

The policies governing the acquisition process, specifically the DoDI 5000.1, DoDI 5000.2, and the NSS 0301, were described as being too prescriptive. This comment reflected the respondent's view on guidance for large satellite developments as compared to the philosophy being pursued under ORS. The respondent identified the development requirements for large satellite systems as being driven by models defined in policy, in contrast to the ability of the small satellite design for ORS to respond flexibly to the needs of the user.

Nine respondents provided their insight on how flexibility could be applied to improve our current process; several of these comments provided notable insights. The Program Objective Memorandum (POM) cycle was identified as an opportunity to implement real options. One respondent asserted that real options should be used during

the POM process to provide value assessments for capability and technology investments. The respondent commented that, as currently structured, the POM makes commitments to invest years in advance with little opportunity to change. As a result, the investments are “rarely relevant...as things have changed dramatically.” The proposed value assessment would allow for the investment opportunities to adjust as necessary.

Another respondent identified the need to use real options to develop flexible architecture in our future weapon systems. The respondent asserted that real options could be used to develop flexible architectures capable of integrating new technologies; suggesting that a flexible architecture allows new capabilities to be integrated at a lower cost:

Now, if you take the real options of saying, "OK, I have a platform that we can't predict the future for, let's not even think that we can and be clever about it. Let's design the architecture so that it can accept new things as they emerge. Actually that saves us money right now, because I don't have to buy the whole thing. I can accept things as they emerge. Also, because I can accept new things, this allows me to change, based on the mission, which then also decreases my cost, because I don't have to make a major rework to something that was fully integrated."

One respondent identified the need to create a business model that anticipates and is responsive to the needs of the market. To accomplish this, the respondent suggested the need to change the paradigm of our current system, from building large, expensive systems to building small, cheap systems. These smaller, cheaper systems could be built in greater quantities to satisfy a variety of needs in the market as well as adapted quickly to address the reactions of the market.

Flexible Response To Future Events

Discussions relating to the theme of a “flexible response to future events” identified three focus areas: the need for flexible architectures, the ORS model for flexibility, and modular standards, as presented in Table 15.

Table 15 *Flexible Response To Future Events*

Response Summaries
<ul style="list-style-type: none">• Develop systems/architecture to allow for future flexibility and new technologies• System architectures with longer life cycles must be flexible to exploit emerging technology• ORS Enables tactical flexibility within operating environment• ORS Enables tactically responsive capabilities• ORS Three tiered architecture provides flexible response to user needs• ORS model requires modularity to accept future missions/payloads• Modularity supports quicker and more cost effective recapitalization• Modularity offers better integration of new technology and economies of scale• Gain flexibility through common standards accepted by industry• Build flexible standards and modules that do not limit future decisions

Several respondents provided comments on the need to develop systems with flexible architectures. The comments were consistent in describing the need for systems that effectively integrate new technologies, noting that this is an essential need as the rate of technology increases. These comments were predicated upon the notion that although existing systems are capable of integrating new technologies, the time and expense are exceedingly high. One respondent commented that this issue will become increasingly important as the number of systems we develop decreases and the age of these systems increases.

Several respondents provided their insights on the ORS model for flexibility, citing the advantages and benefits of this model. One respondent identified the ORS three tiered approach to addressing capability needs, which is currently being discussed by ORS stakeholders. The model proposes three tiers of responsiveness: 1) tier one provides capabilities within hours, through the use of existing on-orbit assets; 2) tier two provides capabilities within weeks or months, through the identification of systems already at some level of integration; and 3) tier three which provides capabilities within a year in response to unforeseen needs. Another respondent commented on the ability of the ORS model to provide tactically and operationally responsive capability to commanders in the field. The respondent noted a conversation with members of U.S. Strategic Command (USSTRATCOM):

And he looks at ORS from that aspect that we just talked about. You got a marine tank commander scooting across a desert somewhere with a 50 year old map. And if you could, you know, quickly send a request to a satellite to get an image of what's over the other side of the hill, or even the day before you did your operation, you could say, "Give me a picture of this city. I just need to know if the bridge is still there." That's the kind of information he's looking for. So he looks at ORS very much from getting information down, in his words, "The last tactical mile."

Several respondents identified modularity as a key concept for the ORS initiative and the TacSat programs. The respondents commented that modularity is an enabling concept for the ORS initiative because it allows for quicker and more cost effective integration of technologies. Respondents universally advocated the concept of modularity, suggesting that modular designs offered better integration of future technologies and better economies of scale when compared to standardized buses. The limitations of standardized buses, compared to modular buses, were noted several times as the

respondents commented on standardized buses having less flexibility for integrating new technologies. Specifically, respondents noted that standardized buses must be over-designed in order to effectively integrate new technologies and as a consequence are not economical in small quantities.

Risk Analysis

Discussions relating to the theme of “risk analysis” were broached in the context of two program-specific issues: parts qualification and testing; and managing program risks, as presented in Table 16.

Table 16 <i>Risk Analysis</i>
Response Summaries
<ul style="list-style-type: none">• Quantify risks for boss• Managing risk in light of need for program advocacy and funding• Radiation environment creates an unknown risk for certain components• Radiation testing for COTS parts• Cost of information• Need to balance objectives with customer expectations• Need to balance scope and risk• Need to balance risk in light of social and political expectations• Need to balance objectives with customer expectations

The respondents that provided comments relating to risk analysis were members of a program team and identified specific instances within their program that either required risk analysis or would benefit from risk analysis. One respondent identified an issue within their program that required an evaluation of program risk versus the cost of a particular test. For this issue, the respondent noted that a real options analysis would help

them quantify the value of their option to test; and provide them with the necessary information to determine their next course of action. Two other respondents commented on their need to balance the scope of their program efforts with the expectations of their customers. Specifically, the respondents noted that as the scope of their program grew, they did not effectively manage the risks of their commitments, which resulted in them failing to satisfy all of their customer's expectations. The respondents commented on the need for an evolving risk analysis.

Secondary Research Question #2 Observations

The second question, "how can the acquisition system benefit from a real options framework," focused on identifying the particular benefits of implementing a flexible and responsive systems framework, such as a real options framework. In this context, benefits involve improvements to aspects of the acquisition system, such as processes and policies that facilitate the execution of system design or systems acquisition. The analysis of the interview transcripts identified 24 responses related to the second study question. A review of these responses identified seven common themes, as presented in Table 17. Of these seven themes, the majority of the responses were related to: an alternative business strategy, flexible response to future events, and flexibility in system design. As some of the themes identified for study questions one and two are similar, the following discussions will address three different themes: create a business case for industry, provide a rapid response to future events, and create learning options.

Table 17 <i>Benefits of Real Options</i>	
Themes Relating to Benefits	
1.	Alternative Business Strategy
2.	Flexible Response To Future Events
3.	Flexibility For System Design
4.	Industry Business Case
5.	Rapid Response To Future Events
6.	Learning Option
7.	Capitalize On Emerging Capabilities

Industry Business Case

Discussions relating to the theme of creating an “industry business case” focused on the need to motivate the industrial base to support the goals of the ORS initiative, as presented in Table 18.

Table 18 <i>Industry Business Case</i>	
Response Summaries	
•	Congressionally added resources to motivate industrial base
•	Driving the industrial base through development of standards
•	Opportunity to engage industrial base

A critical part of the ORS strategy is the development of a standard bus interface. Developing a standardized bus interface would facilitate more efficient integration, therefore enabling a wider variety of payloads to be integrated with the ORS satellites. The intent of the strategy is to develop a government and industry standard. To facilitate the development of this standard, a government and industry Integrated Systems Engineering Team (ISET) was assembled to codify the standard.

One respondent commented that pushing for modularity in ORS is setting the pace for market standards. The respondent commented which industries that typically supported large satellite developments would have to support the development of components and systems for small satellites in order for the ORS strategy to realize the benefits of modularity. As a result, the government would become a driving force for industry investments:

The United States government, instead of imposing standards, is going to start driving the market, because they are a large share of the market.

Another respondent commented on the benefits of having the industrial base supporting modularity. The respondent noted that to achieve the type of flexibility envisioned by the ORS initiative with a standardized bus would require a significant commitment of resources as a result of the economies of scale. This would not present the proper case for ORS as an affordable system. The respondent noted that with the support of industrial base, the move to modularity would enable better economies of scale and support the goal of quicker, cost effective capability:

Now, if you had some type of modular architecture, you can engage your industrial base to start recapitalizing those assets in a much quicker and more cost-effective way.

Another respondent identified that Congress also recognizes the need to stimulate the industrial base to achieve the results of the ORS initiative. The respondent identified that Congress provided \$20-\$25 million to invigorate second and third tier space providers to support the ORS initiative.

Learning Options

Discussions relating to the theme of creating “learning options” discussed benefits of the ORS strategy for learning options, as presented in Table 19.

Table 19 <i>Learning Option</i>
Response Summaries
<ul style="list-style-type: none">• Plug and play reduces risk for large satellite industry• Buy down future risk

A respondent noted that a key element of the ORS strategy is the concept of providing learning options by reducing technology risk through operational experiments. The respondent noted that the TacSat programs are currently involved in experiments involving plug and play components:

Whenever we're flying something we've got to smartly have technology inserted into it in order to buy down where the future is. So TACSAT III has elements of the plug and play satellite integrated into a secondary and tertiary experiment...so even with these systems, you smartly insert the next step, so you can always buy down your next evolution and see where it fits.

Another respondent echoed these thoughts in their comments on the ability to leverage technology for other industries. The respondent noted that plug and play components are integral to the concept of a flexible and responsive satellite. In support of this concept, the TacSat-III experiment is developing and demonstrating plug and play components through operational experimentation. The respondent noted that knowledge gained by this effort could be leveraged by large satellite industries to reduce risk in their development efforts.

Rapid Response To Future Events

Discussions relating to the theme of a “rapid response to future events” broadly discussed topics relating to policies and initiatives that support this theme, as presented in Table 20.

Table 20 <i>Rapid Response To Future Events</i>	
Response Summaries	
<ul style="list-style-type: none">• Established four tech areas for responsive space• Responsive decision cycle• Quickly deliver low cost capability	

A respondent identified that Air Force Research Laboratory (AFRL) has established four technology areas supporting the responsive space technology thrust: plug and play modularity, TacSat II, TacSat III, and modeling and simulation.

A respondent discussed the notion of balancing power in space. The respondent noted that as space technology proliferates, it is important for the DoD to be able to respond “inside of the decision cycle” of any competition. The respondent further noted that new space policy creates greater flexibility in ways to respond to space warfare. In particular, the respondent noted that developing satellites that can be developed and deployed at a very low cost would provide a significant advantage over competitors in space.

Secondary Research Question #3 Observations

The third question, “what are the challenges to effectively implementing a real options framework,” focused on identifying the challenges facing the ORS initiative that would present similar challenges to a real options framework. In this context, challenges

could be the result of social, political, or procedural impediments. The analysis of the interview transcripts identified 44 responses related to the third study question. A review of these responses identified 11 common themes, as presented in Table 21. Of these 11 themes, a majority of the responses were related to: competition and inertia, standardization vs. modularity, and how to value flexibility in the DoD.

Table 21 Challenges to Implementing Real Options

Themes Relating to Challenges	
1.	Competition and Inertia
2.	Standardization Vs. Modularity
3.	How To Value Flexibility In the DoD
4.	Flexibility Is Expensive
5.	Process Limitations
6.	Need Organizational Support
7.	Need Industry Business Case
8.	Lack of Authority
9.	Flexibility Vs. Rapid Response
10.	Scalability
11.	Need Smart Buyers

Competition and Inertia

Discussions relating to the theme of “competition and inertia” identified three focus areas: paradigm inertia, stakeholder conflict, and bad management decisions, as presented in Table 22.

Several respondents identified the inertia caused by old paradigms as a challenge to the changes proposed by ORS. The major causes of this inertia were identified as a general lack of understanding or a reluctance to eliminate established competencies. One

respondent noted that an organization when approached to develop a satellite for \$10 million and launch it in a years time responded “we can’t do this,” as a result of their previous experiences in satellite development. The respondent noted that this type of resistance was a result of the organization’s concept of “the way it should be” and not a lack of competence.

Table 22 Competition and Inertia

Response Summaries
<ul style="list-style-type: none"> • Old Paradigms / Old Perspectives • Organizational Inertia • Old Paradigm Resistant To Change • Competing Interests With Lateral Stakeholder • Competing For Limited Funding • Conflict With Lateral Stakeholder • Disruptive Lateral Stakeholder • Stakeholder Disagrees With Concept • Stakeholder Friction • Contractors Will Resist Because Diminishes Earning Potential • Internal Pediment As Result Of Bad Management Decision

Another respondent acknowledged that an organization with a competing interest presented a significant challenge. The respondent described the on-going debate on the merits of standardization vs. modularity as a challenge to meeting the goals of the ORS strategy. The respondent noted that the competing organization is recalcitrant because of its “very well-defined lane in the road” competencies and processes and their desire to maintain them. This competing organization was also identified as a disruptive stakeholder because the organization has a stake in the success of the ORS initiative.

Another respondent identified that the concept of ORS may infringe upon the “rice bowl” of the National Reconnaissance Office (NRO). The respondent suggested that since the NRO is the principal provider of space capabilities for the nation, that the concept of ORS might be identified as a challenge to the roles and missions of the NRO. The respondent further noted that this issue depends on the perspective of the individual:

Part of it is that the viewpoint, when you look at ORS, depends very much on where you sit. The NRO has a very good case to make that if the commander of CENTCOM asks for information today, they can get it to him very quickly. And there are virtually no requests that they're getting today that are not being filled. And they can show that. And they have a very valid point to make. So that's one viewpoint. If you go today and you talk to a tank commander in -- pick your country. And you ask him what kind of space imagery are you getting to support your operations, the answer is none. Zero. We have zero space support. And so in between there are two very different views.

Another responded noted that because of similar goals and objectives, organizations involved in ORS and TacSat would likely compete for limited dollars, thereby potentially creating conflicts between stakeholders.

Flexibility is Expensive

Discussions relating to the theme of “flexibility is expensive” broadly addressed the debate regarding the expense of flexibility in the DoD, as presented in Table 23.

Table 23 <i>Flexibility Is Expensive</i>
Response Summaries
<ul style="list-style-type: none"> • Lack Of Funding • Is Congress Willing To Fund Large Scale Flexibility • It Costs More To Be Flexible • Require Funding Latitude To Purse Flexibility

A respondent noted that there are on-going debates addressing the scope of what is possible with ORS if no additional funding is provided. The respondent commented that “the barrier today is money; you can be completely flexible with more money.” It was also noted that the enablers to achieving greater flexibility in ORS is minimizing the amount of effort required and that there are current efforts to develop a bus strategy for the ORS satellites that minimizes the expense and effort of integrating multiple payloads. The respondent added that the question remains to be answered if Congress is willing to fund larger scale efforts for developing a flexible system, “are they willing on a larger scale to give that kind of flexibility, say \$100 million?”

How to Value Flexibility in the DoD

Discussions relating to the theme of “rapid response to future events” identified two focus areas, defining flexibility and quantifying flexibility, as presented in Table 24.

A respondent noted that a current challenge of the ORS initiative is clearly establishing what flexibility means. The respondent noted that there are on-going debates with USSTRATCOM to clarify the meaning of flexibility and, based on this definition, when it can be achieved. In a similar response, another respondent noted that the major challenge to implementing flexibility in future acquisition programs is a lack of tools and

models to properly display, quantify, and evaluate flexible concepts without “emotional” debates.

Table 24 *How To Value Flexibility In DoD*

Response Summaries

- Debating Definition Of Flexibility
- Lack Mechanisms To Diffuse Emotional Response
- How Do You Quantify The Level Of Flexibility Needed
- How Do You Value These Decision Trees
- Existing Systems Architecture Set, Not Amenable To Optionality
- What Is The Data That's Going To Trigger The Option Decision

Several respondents provided comments on the challenges to valuing flexibility.

One respondent noted that a principal challenge is determining what level of flexibility should be applied in a system and how it should be valued. This issue is a point of discussion in the design of the modular systems, determining whether modularity should be applied at the component or subsystem level. Another respondent posed the question, how do you put value on decision trees evaluating concepts like a tiered architecture of large sat, microsat, aerostat, and UAV; subsequently asserting that no one has attempted this analysis.

Summary

This chapter offered a comprehensive review of the observations and findings of the case study conducted on the ORS initiative and the TacSat experiments. The results offered insights into the opportunities, benefits, and challenges of implementing a flexible and responsive satellite system architecture. These results also offer some

insight into the potential for applying flexible strategies, such as a real options framework, on a potentially larger scale in other acquisition programs. The final chapter will review the conclusions and recommendations formulated as a result of this investigation.

V. Conclusions and Recommendations

Introduction

The primary research objective for this study was to explore the opportunities for implementing a real options framework in the DoD acquisition system. The secondary objectives were to identify how real options could be implemented, to qualify the benefits of this implementation, and to identify potential challenges or impediments. The principal instrument for evaluating these research objectives was a case study of the Operationally Responsive Space (ORS) initiative and its Tactical Satellite (TacSat) experiments. This initiative was selected for observation because elements of its strategy offered similar comparisons to the concepts of real options. This chapter will present the conclusions of this research, identify limitations to this research method and offer, recommendations for further evaluation.

Conclusions

The primary objective of this research was to identify opportunities within the acquisition system for adapting a real options framework. The secondary objectives were to identify: how real options could be applied within the acquisition system, the potential benefits to be reaped from implementing real options, and the challenges within the acquisition system that could impede implementation. It is this researcher's belief that the research goals for this study were met and the results of this effort will provide motivation for additional study into the nascent concept of real options in the DoD acquisition system.

The primary research question sought to identify opportunities within the DoD acquisition system for the implementation of a real options framework. The ORS initiative provided an ideal case study for this investigation. The core intent of the ORS initiative to develop and demonstrate a system architecture for providing flexible responses to the dynamic needs of the Combatant Commanders bears similarities to the characteristics of an organization that could gain value from the implementation of a real options framework. This intent bears similarity to the two elements described by Copeland and Keenan (1998b): an operating environment with a high degree of uncertainty and the likelihood that new information will be discovered and the ability of organizational management to strategically respond to this new information. The interviews conducted with members involved in the ORS initiative provided specific insights into these elements and intent, describing how the strategy for this initiative contributes to the improvement of the acquisition process and support to the warfighters. The concepts of an alternative business strategy, the need for flexibility to respond to future events, the importance of flexible system designs, and the need for improved methods of risk analysis were predominant in the comments provided by these respondents. Despite the stated benefits and gains proposed by the ORS initiative and the development efforts of the TacSat programs, the respondents also identified several particular challenges to the execution of the ORS vision. Of particular interest were the respondent's acknowledgments of the challenges posed by lateral stakeholders with competing interests and motivations to maintain the status quo, the challenge of appropriately assessing the value of flexibility for the DoD, and the perception that flexibility is expensive.

The ORS case study offered five propositions for the implementation of a flexible framework such as real options. Of these five propositions, several were given particular emphasis: alternative business strategy emphasizing flexibility, system architectures and design philosophies focused on flexibility, and the need to improve our ability to evaluate investment risks. In the context of an alternative business strategy, the emphasis was placed on providing greater flexibility in our processes and practices. The key notion expressed was that our current processes are too restrictive and incapable of responding to the rapidly evolving needs of our combat forces and the asymmetries of our current security environment. It was also suggested that future systems and system architectures would require increasing levels of flexibility to adapt to the rapidly changing security environment, as the asymmetric threats that we face require the ability to dynamically adapt to remain competitive. Finally, it was suggested that real options could be employed as both a systems management and a systems engineering tool to evaluate risks. Specifically, a real options evaluation at the systems management level could provide a means for quantifying and evaluating programmatic investment decisions; and real options “in” could be applied in the analysis of design trades for complex systems to identify and the quantify decisions regarding flexibility to accommodate future changes.

The review of the ORS initiative identified seven potential benefits of a flexible framework such as real options. Several of these proposed benefits were given particular emphasis: alternative business strategy emphasizing flexibility, system architectures and design philosophies focused on flexibility, and the ability of flexibly designed systems to integrate future technologies and capabilities. The benefit of an alternative business model utilizing a real options framework is the ability to respond to the urgent and

changing needs of the user market. Specifically, through the use of a real options framework, the acquisition system would be better suited to evaluate and consider investment opportunities to reduce development risk and provide capabilities in a timely manner to its customers. Finally, it was suggested that our future systems and system architectures would require upfront design considerations for integrating emerging technologies. As current and future systems remain in our inventory for longer periods of time, the need to integrate new technologies and capabilities with less effort and expense will become a critical element of our ability to maintain our competitive advantages.

The ORS case study identified 11 challenges experienced in the execution of the responsive space transformational strategy, which could also serve as impediments to the implementation of a real options framework. Of these challenges, several were given particular interest: competition and inertia, the expense of flexibility, and the means of valuing flexibility in the DoD. Resistance to change was identified as the most significant challenge faced by the ORS initiative and would likely be the greatest challenge facing the adoption of a real options framework. It was suggested that the introduction of new ideas and ways of conducting business could conflict with the established competencies of related organizations and lead to conflicting paradigms. This type of paradigm inertia could preclude effective execution if the conflict is with lateral stakeholders in supporting or supported positions. Conflict could arise from organizations with competing interests or conflicting processes, which could also lead to programmatic inertia. Efforts to implement a real options framework would likely encounter similar levels of resistance and programmatic conflicts.

The cost of system flexibility was also identified as a potential challenge to the implementation of flexibility in system design. Although flexibility was identified as a strategically important concept in the execution of systems acquisition efforts and the design of engineering systems, the costs of this flexibility and the willingness of the Congress to fund it was identified as a limiting factor. As the concept of real options relies on the execution of options to provide flexibility to respond to future uncertainties, the willingness of the DoD and the Congress to fund this additional level of flexibility must be a major consideration in the execution of a real options framework.

Finally, determining the value of flexibility for DoD systems was identified as a specific limitation for the real options framework. There are two elements to this limitation: identifying the appropriate measures for using real options as an analytical framework and determining the appropriate means to qualitatively value flexibility. The derivation of equivalent measures for stock price, risk free rates of return, time to expiration, and volatility is a difficult measure for the defense environment as there are no clear corollaries. Lacking the appropriate measures to quantitatively value flexibility, it was suggested that a qualitative measure would be the necessary. However, agreements on the appropriate measures and the necessary tools to properly determine this value were also identified as shortcomings.

In conclusion, it is the researcher's opinion that these observations provide an indication of the opportunities and benefits of implementing a real options framework. The adoption of a real options framework in our acquisition management framework would offer the benefit of better execution of acquisition program investment opportunities. By exercising the appropriate options at a program milestone, such as

deferring or abandoning poorly performing programs, the acquisition system can achieve a better focus on the capabilities that generate the greatest value to the warfighting customers. This concept offers particular benefits during the early program phases of Science and Technology (S&T) investments and Concept Refinement. It provides an incentive to explore more technologies and concepts without the need for further commitments if results prove unfavorable. As expressed in the ORS strategy, these “learning options” also generate value because the knowledge gained can be applied to other related efforts. The design of flexible systems and system architectures also offer potentially substantial benefits. With fewer large scale development efforts, greater monetary commitments per development effort, and the likelihood of longer service lives, flexible system designs afford the acquisition community and its customers the opportunity to keep the available systems competitive and relevant in the face of a dynamic security environment. In concert with this notion is the idea that flexible systems can integrate new technologies and capabilities quicker and at a lower cost than what is currently capable. This affords the warfighter the option to economically pursue newer capabilities sooner, instead of waiting for planned major upgrades. Finally, the concept of a real options framework presents the DoD with an opportunity to inculcate the notion of flexibility, a key concept for defense transformation, in its processes, practices, and systems.

Limitations of Study

As previously mentioned, the principal limitations to this study are the choice of a case study design and the qualitative methods used to analyze the interview data. The

inductive, exploratory case study design used for this study has several limitations. First, although exploratory research provides provocative insights and hypothesis for further study, it does not lend itself to yielding actionable, decision-making insight. As a result, the conclusions and recommendations provided by this study will require additional exploration to validate. Additionally, exploratory case study designs have limited external validity. It is generally accepted that these types of studies are limited to generalizations to theory (Yin, 2003). Finally, construct validity for case studies is often criticized due to its lack of sufficient operational measures and the subjective nature in which data is collected (Yin, 2003).

The interview analysis for this case study also presented two significant limitations. The first limitation is the interview data used for this study. The form of the interview subject responses, as open-ended discussions or statements, limited the degree to which responses could be clearly categorized with investigative questions. As a result, a qualitative method was used to identify responses and themes related to the research questions. The methods utilized to identify related responses and to determine the themes within the responses was highly subjective and relied on the researcher's knowledge and opinion. These methods may inject researcher bias into the results of the study. Finally, the qualitative approach to interview data analysis may limit the ability of future researchers to repeat the results of this study.

Recommendations

The examination of the ORS initiative and the TacSat experiments identified several efforts to improve the business model for the development and delivery of

satellite capability for the operational and tactical levels of combat. The efforts identified by these transformational activities were the shift from large scale, unique, low number satellite developments to small, standardized, modular satellite systems produced in large quantities; as well as the notion of early exploration of concept and technology pairings. This premise of an alternative business model was also expressed by the interview subjects and identified as the principal opportunity and benefit of a flexible system framework such as a real options framework. The particulars regarding the implementation of a new business model were not explicitly stated; however, several notions were offered that would benefit from further exploration.

The examination of literature on real options and the review of the transformational strategy for ORS identified a common theme: creating value through the creation of options. It is this researcher's opinion that the current acquisition environment is becoming less conducive to the execution of long development cycle, large scale acquisition programs. As systems become more complex and the rate of technology continues to increase, the impact of long development cycles and the expense of large scale acquisition programs will likely become more pronounced. Flexible and responsive business processes were identified as a key concept for the ORS initiative and a significant observation of the interviews, particularly through the execution of small scale, high volume acquisitions. This strategy focused on achieving lower budget requirements and faster, more flexible, response times. The exploration of similar strategies in other acquisition programs, such as creating program value through the creation options, offers the opportunity to explore alternative philosophies and strategies for the acquisition business model.

The ORS strategy of operational experimentation presented a method to assess technologies and operational concepts in a minimum risk environment. By conducting these efforts in an iterative manner, prior to the execution of an acquisition effort, the ORS initiative can identify promising technologies for further investment or identify those not sufficiently mature. These “learning options” also offer the benefit of reducing risk for the operational capability, as the testing in an operational environment provides the warfighters with the opportunity to witness actual system performance. An added benefit of these early risk reduction efforts is the knowledge gained by programs utilizing similar technologies or concepts, such as the industrial base, and their ability to gain leverage from the early, exploratory efforts. It is this researcher’s recommendation that the concept of “learning options” or operational experimentation be further explored for use on other acquisition programs.

The examination of the ORS initiative and the TacSat experiments also identified the need for flexibility in our acquisition system processes and system designs to respond to unanticipated future events and to capitalize on emerging technologies. The ORS strategy for achieving these goals relies upon the development of standardized satellite buses and the use of modular systems, as well as cooperative investigations into technologies and concepts with the acquisition community, operational community, and industry. Although there are current efforts within the DoD to execute such frameworks, the proposals and strategies of the ORS initiative offer additional perspectives on a means to achieve a flexible and responsive system. It is this researcher’s recommendation that organizational processes and systems design philosophies expressed in the ORS initiative be examined for applicability to other acquisition programs.

This study offered an exploratory look at the potential for a real options framework in the DoD acquisition system. Based on the results and conclusions of this study there are several possible areas of future study. These additional areas of study include: development of a quantitative framework for evaluation of real options in the defense acquisition system, development of a quantitative framework for conducting a real options “in” evaluation of an engineered system for a defense acquisition program, and identification and codification of guidance and policy for the implementation of a real options framework within acquisition programs at the systems management level and the systems engineering level.

Appendix 1: Investigative Questions

QUESTIONS ABOUT SYSTEM STAKEHOLDERS:

Who are your stakeholders/customers inside the organization?
Who are your stakeholders/customers outside the organization?
How have the stakeholders changed over time?
What is the impetus for these changes?
Who are the future stakeholders of the system?
What capabilities do they desire?
Are they different from existing capabilities?

QUESTIONS ABOUT ORGANIZATION:

Who in the organization requires information from you?
Who in the organization requires product from you?
Who in the organization requires money from you?
Who in the organization delivers information to you?
Who in the organization delivers product to you?
Who in the organization delivers money to you?
(Follow on questions seeking to describe the nature of these interactions)
How has the organization changed over time?
What was the impetus for these changes?

QUESTIONS ABOUT SYSTEM OBJECTIVES:

Are the objectives for the system defined/documented? If so, may I see them?
What do you perceive are the objectives for the stakeholders you described above?
What are your objectives for the system?
What do you perceive are your customer's objectives?
What are the organization's objectives?
How have the system objectives changed over time?
What was the impetus for these changes?

QUESTIONS ABOUT SYSTEM ACTIVITIES:

Do you have a work breakdown structure/documents that describe your activities?
If so, (may I see them) are these documents accurate? What are the deviations? Explain.
What activities do you perform for your job?
What activities do you perform to support your objectives?
What activities do you perform to support your internal customers' objectives?
What activities do you perform to support your external customers' objectives?
What activities are required in order for you to perform your activities?
What activities are affecting your activities?
Describe the nature of these affects/interactions
What activities are affected by your activities?
Describe the nature of these interactions
What are the attributes/measures of performance for your activities?
How have the activities changed over time?
What was the impetus for these changes?

QUESTIONS ABOUT ENGINEERED SYSTEM:

What elements in the engineered system are your responsibilities?
What elements in the engineered system are affected by your elements?
What elements in the engineered system affect you elements?
Describe the nature of these interactions?
What are the key system parameters for the elements under your responsibility?
What are the attributes of engineered systems?
How has the engineered system changed over time?
What was the impetus of these changes?
Thinking back through the design iterations of previous systems...which elements in the physical structure has changed most (least)? Why was the driving force behind the changes (customer needs, innovation, architectural philosophy, other)

QUESTIONS ABOUT SYSTEM DRIVERS:

What are the factors beyond your control have the greatest impact on the system objectives?
What are the factors beyond your control have the greatest impact on the organization?
What are the factors beyond your control have the greatest impact on the engineered system?
What are the factors beyond your control have the greatest impact on the activities?
What is the nature of these interactions?
How rapidly is the technology supporting the system changing?
How have the operational requirements for the system changed, likely to change?
What was the impetus of these changes?
What are your greatest cost risks? Schedule risks? Performance risks?
What do you consider the greatest impediments to your program's success? (FAR, Cost Instability, Organization)
What do you consider the greatest enablers?

QUESTIONS ABOUT CONTRACT STRATEGY/EXECUTION:

What was the contracting strategy chosen for the TacSat-1 program? Please provide a description of the contract type(s) used. Please identify significant contract options included. Please identify significant contract schedule events.
Were any FAR/DFAR waivers requested and granted? Please identify which waivers were requested and granted.
Were any DoD 5000 waivers requested and granted? Please identify which waivers were requested and granted.
Are TactSat-2 through TacSat-6 contracted as follow-on pre-planned product improvement (P3I) efforts under the original contract? If no, what is the contracting strategy planned for these follow-on efforts (Reference Question 1)?
Were the contract(s) executed for TacSat-1 competitively selected or sole source? If sole source, what justification was used?

QUESTIONS ABOUT ACQUISITION STRATEGY:

What was the acquisition strategy chosen for the TacSat-1 program?

What, if any, acquisition initiatives have been employed (Cost As an Independent Variable, performance based procurements requirements, commercial standards and products, etc.)?

What, if any, critical events were required at program decision milestones?

Has a transition plan developed to move from experimentation to full-scale acquisition program?

QUESTIONS ABOUT PROGRAM EXECUTION:

Was program funding identified and committed for the entirety of the program or was out-year funding, if any, not committed?

Were key program decisions/trades executed at the oversight level or the program execution level?

ADDITIONAL KEY QUESTIONS:

What are the major sub-systems of the TacSat spacecraft?

What are the key interfaces (mass, energy, information and authority) that connect these sub-systems?

What are the key expected system changes during operational life? Description of the pace and variety of those changes

How do such system changes (e.g. payload swap-out, bus changes, launch vehicles adaptation, communication system adaptation) propagate through the system?

How was the sub-system architecture developed? What were some alternative architectures? Who made the choice? On what criteria?

Repeat the above for each version of TacSat (1-6)

How does TacSat fit within the larger defense space establishment as a system?

What are the key external interfaces of the TacSat?

Does the TacSat participate in any systems-of-systems? Describe the interfaces between TacSat and the other constituents systems?

How does TacSat fit within the larger defense space establishment as a program?

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